The American Midland Naturalist

Devoted to Natural History, Primarily that of the Prairie States

Founded by J. A. Nieuwland, C.S.C.

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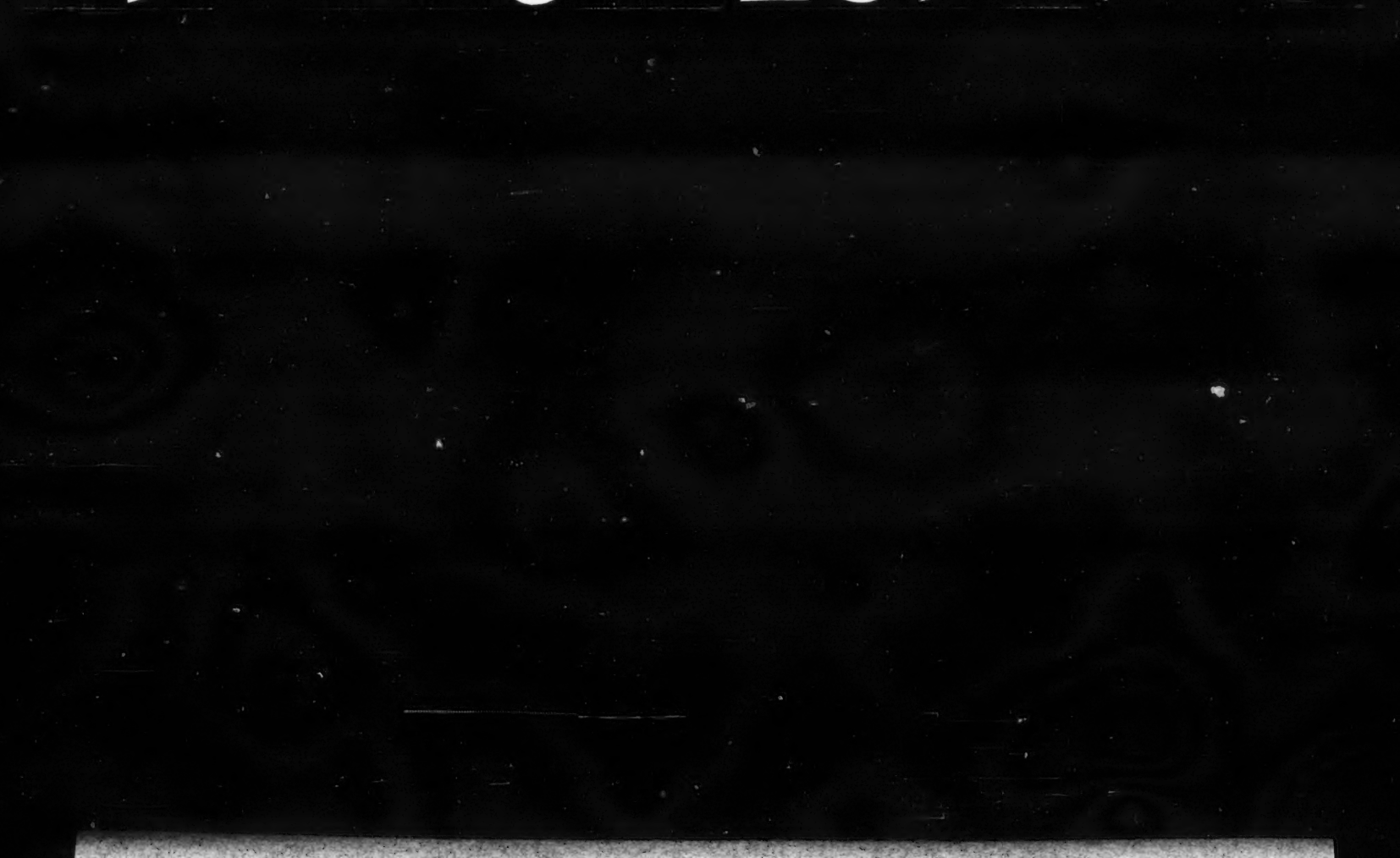

The American Midland Naturalist

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VOL. 18 NOVEMBER, 1937 No. 6

The Filamentous Algae of the West End of Lake Erie

Lewis Hanford Tiffany

Introduction

This paper is the second in a series of contributions on the algal flora of the west end of Lake Erie. The writer (1934) in the first report dealt with the plankton algae represented especially by the Chlorophyceae, the Myxophyceae, the Heterophyceae (Xanthophyceae), Chrysophyceae, and the Euglenophyceae. The Dinophyceae, the Diatomophyceae, and the Desmidiaceae were not studied sufficiently at that time to warrant their inclusion: they will receive attention in a later account. Filamentous greens, bluegreens, and yellow-greens are included in this report. Freshwater members of the Rhodophyceae are not so far known for the region.

It is impossible of course sharply to separate "filamentous" from "plankton" forms of algae. The terms are defined on different bases and are thus not strictly comparable. Numerous filamentous algae—plants in which cell division results in a thread of cells known as a filament—are found as proper or accidental constituents of the plankton. In order to avoid duplication and at the same time make both reports as complete as possible, such planktonic forms of filamentous algae as appear in the first paper will be referred to here by name only.

The algae discussed in this paper have been collected in the islands region of the west end of Lake Erie (see Map) during the summers of 1927-36, while the writer was a member of the staff of the Franz Theodore Stone Biological Laboratory of the Ohio State University. Many of the plants were collected by students during the regular field excursions of the classes in freshwater algae. To them the writer is much indebted.

The total number of filamentous forms recorded for the region to date is 145, made up of 101 greens, 40 bluegreens, and 4 yellow-greens. The number is not large when one thinks of the prairie regions of the central west or of the southern coastal plain. Scanty collections in early spring cannot account for the relative paucity of different species. The extensive marshes of East and West Harbor, as well as those of the entire western mainland, are somewhat disappointing in variety of fruiting filamentous algae. It does not seem possible to account for it on the presence or absence of any special environmental factor or factors. The sum total of environmental influence necessary for abundant fruiting of filamentous forms is somehow deficient. The explan-

ation is not clear. The best season for fruiting species seems to be late July to early September.

The novelties are *Binuclearia eriensis* and *Stigeoclonium gracile* (W. & G. S. West). This brings the total of new species and combinations described for the region to twenty-four. Most of the species are previously unreported for Ohio. The grand total of all algae reported for the region is 435 species, varieties, and forms. The following table will show distribution by classes, to date:

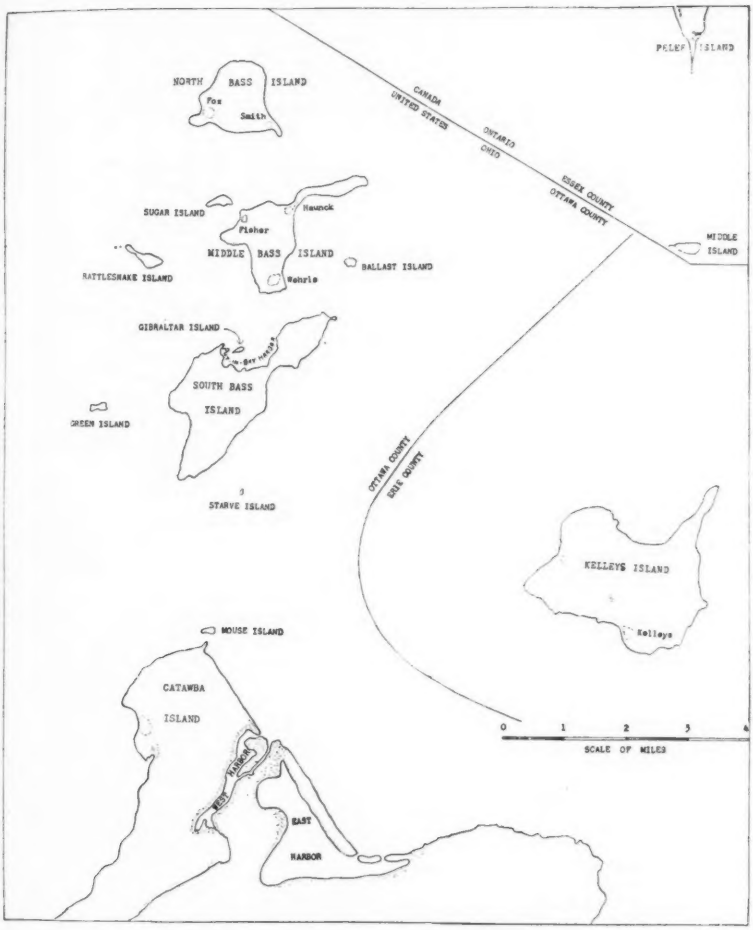
Class	Species	Genera	Varieties
Myxophyceae	69	25	9
Chrysophyceae	12	7	0
Heterophyceae	15	8	3
Chlorophyceae	260	84	51
Euglenophyceae	16	4	0
Total	372	128	63

Keys to both genera and species are provided, and each alga is represented by at least one figure. Most of the figures are original, but proper credit is given for those taken or adapted from previous publications.

Algal Habitats of the Region

The area covered especially by the survey is shown on the map just below. The three Bass Islands—South, Middle, and North—lie near the Ohio shore some few miles north of a peninsular projection of the mainland known as Catawba Island. South Bass Island (sometimes known as Put-in-Bay Island) is the largest of the three, having an area of 1,224 acres, and is the least interesting algologically, except for its protected inlets. In making a site for the magnificent Perry Memorial, the only pond on the island was filled up. Middle Bass Island with an area of 742 acres contains three rather extensive ponds or pond-like marshes referred to in this report as Wehrle, Fisher, and Haunck. Near these marshes, particularly during periods of high water, are other much smaller ponds. North Bass Island (formerly Isle St. George) with an area of 696 acres contains two marshes, Fox and Smith, and a few "high-water" ponds. The water of these marshes is generally shallow and is regulated by the level of Lake Erie, although there is no direct connection except by seepage and during violent storms.

Kelleys Island lies about 3¼ miles north from the Ohio Shore at Marblehead and has an area of 2,800 acres. An extensive marsh-like area (Kelleys Pond) near the docks on the southwest shore of the island may become very shallow in seasons of low water level. A similar swamp occurs near the west shore, the pond-like portion being called Carp Pond. The most interesting algal habitats on Kelleys Island, however, are the quarry pools. These are usually very shallow and temporary, but in some cases are as much as forty feet deep and quite permanent. The pools are located at various places in the abandoned limestone quarries, and have a pH of about 7.3.



MAP OF THE ISLANDS REGION OF THE WEST END OF LAKE ERIE

(Adapted from Put-in-Bay and Kelleys Island Quadrangles of the United States Geological Survey.)

Pelee Island in Canadian water is much the largest of the islands in Lake Erie, having an area of some 10,000 acres. On the southwest shore lies Fox's Marsh. On the west shore are drainage ditches, and near West Dock is a quarry pool of considerable depth, usually covered with duckweeds. During early summer, however, this quarry pool has an interesting plankton flora. An abandoned canal on the northeast corner of the island is quite productive in early summer.

Put-in-Bay Harbor is a semicircular inlet on the northerly shore of South Bass Island with Gibraltar Island in such a position as to give considerable protection to the harbor from wind and wave action. In the harbor are located three separate small inlets having semi-pond characteristics and known as Terwilliger's Pond, Squaw Harbor, and Hatchery Bay. The water is shallow, is much protected from winds, and in late summer may become choked with such aquatic flowering plants as *Potamogeton americanus, P. pectinatus, P. compressus, Elodea canadensis, Naias flexilis, Vallisneria spiralis, Ceratophyllum demersum, Myriophyllum spicatum, Scirpus validus,* and *Nelumbo lutea.* As a matter of fact the ponds of the islands are losing their pond characteristics due to the encroachment of aquatic macrophytes.

East Harbor and West Harbor, large enough to be considered lakes, are on the mainland peninsula of Catawba Island. West Harbor is a narrow extension nearly two miles long connected to the lake by a narrow channel less than a mile in length. East Harbor extends along the lake for a distance of about a mile and inland nearly two miles. It is connected to the lake by a very narrow channel about a hundred yards long and fifty yards wide. These harbors are fringed with cat-tails, water lilies, bulrushes, pondweeds, and other emergent and floating aquatic flowering plants.

The algae were collected in the usual manner and examined when possible in the living state. An excellent preservative is Transeau's solution made up of 6 parts water, 3 parts 95% alcohol, and 1 part formalin.*

Systematic Section

CHLOROPHYCEAE

Key to the Genera

1. Cells solitary or in irregular aggregates ---------- 2
1. Cells definitely filamentous ---------- 3
   2. Cells with long setae ---------- *Chaetosphaeridium*
   2. Cells without setae ---------- *Protococcus*
3. Filaments septate ---------- 4
3. Filaments coenocytic ---------- 24
   4. Chloroplast an axile plate ---------- *Mougeotia*
   4. Chloroplasts two star-like bodies ---------- *Zygnema*
   4. Chloroplasts elongated, often spiral, bands ---------- 5
   4. Chloroplasts otherwise ---------- 6
5. Conjugation by genuflexing ---------- *Sirogonium*

* For more special directions regarding the collecting and preserving of algae the reader is referred to Tiffany: *Algae the Grass of Many Waters.* Chas C. Thomas, Pub., Springfield, Illinois. (In press).

5. Conjugation by formation of tubes ——— *Spirogyra*
6. Plant discoid or pulvinate ——— *Coleochaete*[1]
6. Plant neither discoid nor pulvinate ——— 7
7. Plant prostrate on other algae ——— *Aphanochaete*
7. Plant partly or wholly erect ——— 8
8. Filaments branched[2] ——— 9
8. Filaments unbranched ——— 16
9. Branches numerous and common ——— 10
9. Branches few ——— 15
10. Cells multinucleate, chloroplasts numerous ——— 11
10. Cells uninucleate, chloroplast usually single ——— 12
11. With akinetes ——— *Pithophora*
11. Without akinetes ——— *Cladophora*
12. Setae lateral on vegetative cells ——— *Bulbochaete*
12. Setae terminal, or none ——— 13
13. Plant conspicuously differentiated into main axis and branches ——— *Draparnaldia*
13. Plant obscurely so differentiated ——— 14
14. Filaments in dense gelatinous masses ——— *Chaetophora*
14. Filaments not in dense gelatinous masses ——— *Stigeoclonium*
15. Growing on shells of turtles ——— *Basicladia*
15. Growing elsewhere ——— *Rhizoclonium*
16. Filaments with conspicuous gelatinous envelope ——— 17
16. Filaments without conspicuous gelatinous envelope ——— 19
17. Cells with markedly stratified walls ——— *Cylindrocapsa*
17. Cells with inconspicuously stratified walls ——— 18
18. Poles of cells flat ——— *Ulothrix*
18. Poles of cells rounded[3] ——— *Geminella*
19. Chloroplast reticulate; cells with apical caps ——— *Oedogonium*
19. Chloroplast not reticulate; cells without apical caps ——— 20
20. Filaments composed of articulated H-pieces ——— *Microspora*
20. Filaments not composed of articulated H-pieces ——— 21
21. Plant multiseriate, except when young ——— *Schizomeris*
21. Plant uniseriate ——— 22
22. Cells without pyrenoids and often in pairs ——— *Binuclearia*
22. Cells with pyrenoids and not in pairs ——— 23
23. Chloroplast on one side; fragmentation of plant common ——— *Stichococcus*
23. Chloroplast a transverse girdle; fragmentation of plant rare ——— *Ulothrix*
24. Coenocyte with transverse constrictions ——— *Dichotomosiphon*
24. Coenocyte without transverse constrictions ——— *Vaucheria*

Class Chlorophyceae
Order *Ulotrichales*
Suborder *Ulotrichineae*
Family *Ulotrichaceae*
Ulothrix Kuetzing 1833

Filaments unbranched, not apically attenuated, frequently attached basally; vegetative cells uninucleate, cylindrical or sometimes barrel-shaped; chloroplast band-shaped, occupying part or the whole of cell circumference, with one or more pyrenoids.

Formation of quadriciliate and biciliate zoospores, of aplanospores, and

1 *Coleochaete irregularis* is often merely an irregularly branched filament.
2 *Rhizoclonium hieroglyphicum* is often branchless; *Basicladia* is usually locally branched.
3 *Geminella minor* has cells with flattened poles.

of akinetes; biciliate gametes; zygotes germinating into daughter protoplasts producing aplanospores or zoospores, haploid filaments of six kinds: plus and minus, producing gametes only; plus and minus, producing gametes and zoospores; and plus and minus, producing zoospores only.

Key to the Species

1. Vegetative cells 7-9 x 6-12μ ---------- *U. tenerrima*
1. Vegetative cells 11-45 x 10-100μ ---------- *U. zonata*

1. *Ulothrix zonata* (Weber & Mohr) Kuetzing (Pl. 11, Fig. 1). Vegetative cells cylindrical or swollen 11-45 x 10-100μ; cell wall thick at maturity; chloroplast usually a median band with several large pyrenoids.

Gibraltar, Catawba, Middle Bass, Big Chick.

2. *Ulothrix tenerrima* Kuetzing (Pl. 1, Fig. 2). Vegetative cells cylindrical, 7-9 x 6-12μ, with thin walls; chloroplast zonate or on one side, with 1 pyrenoid.

Haunck.

GEMINELLA Turpin 1828

Filaments free-floating or sessile, inclosed in a tubular gelatinous envelope; vegetative cells usually cylindrical and variously placed within the envelope: longitudinally adjacent, or remote and in pairs, or equidistant; chloroplast laminate, zonal, usually with 1 pyrenoid.

Fragmentation; akinetes.

Key to the Species

1. Vegetative cells adjacent in tubular envelope ---------- *G. minor*
1. Vegetative cells in pairs in tubular envelope ---------- *G. interrupta*

1. *Geminella minor* (Naegeli) Heering (Pl. 1, Fig. 5). Vegetative cells 2-10 x 3-14μ, lying pole to pole in a tubular gelatinous envelope 8-18μ in diameter.

Haunck, Terwilliger's.

2. *Geminella interrupta* Turpin (Pl. 1, Fig. 4). Vegetative cells 5-8 x 6-15μ, in pairs within a tubular gelatinous envelope 16-20μ in diameter.

Quarry pools on Kelleys.

STICHOCOCCUS Naegeli 1849; emend. Gay 1891

Filaments unbranched, consisting of a few (sometimes solitary) or many cells; vegetative cells uninucleate, cylindrical; chloroplast parietal and laminate, not covering more than one-half the cell circumference, with a single pyrenoid.

Fragmentation; biflagellate zoospores, aplanospores, and biflagellate gametes that are either isogamous or anisogamous.

1. *Stichococcus subtilis* (Kuetzing) Klercker (Pl. 1, Fig. 3). Vegetative cells 5-8 x 6-23μ, filaments not constricted at cross walls.

Terwilliger's.

Binuclearia Wittrock 1886

Filaments unbranched and devoid of gelatinous sheath; cells cylindrical with flattened poles and much shorter cylindrical chloroplasts with rounded ends; space between end of cell and chloroplast gelatinous and lamellose; daughter cells often in pairs, older cells becoming equidistant; chloroplast single, laminate, usually occupying the middle of the cell, without pyrenoid and often with a prominent granule at each end.

Aplanospores, akinetes, and (?) zoospores.

Key to the Species

1. Vegetative cells 2-3 x 8-20μ ---------- *B. eriensis*
1. Vegetative cells 6-10 x 10-70μ ---------- *B. tetrana*

1. *Binuclearia tetrana* Wittrock (Pl. 1, Fig. 6). Vegetative cells 6-10 x 10-70μ.

Terwilliger's, Wehrle.

2. **Binuclearia eriensis** sp. nov. (Pl. 1, Fig. 7) Cellulis vegetativis 2-3μ latis, 8-20μ longis; chlorophoris totum cellulae lumen vix vel interdum fere replentibus; granulis binis in utroque chlorophororum extremo singulis; ceteroqui characteribus generis.

Squaw, Terwilliger's, Haunck.

This alga has been observed in the region for a number of years. Its size has made it difficult to analyze. The absence of pyrenoids, the prominent granules, the faint lamellations of gelatinous material within the cell seem definitely to place it in *Binuclearia*. It is very easily separated, by its small size, from *B. tetrana*, the only other known species of the genus.

Family *Microsporaceae*

Microspora Thuret 1850; emend. Lagerheim 1888

Filaments unbranched, composed of articulated H-pieces; vegetative cells cylindrical or swollen, uninucleate, walls thick or thin; chloroplast perforate, reticulate, and covering entire inner surface of cell wall; pyrenoids none.

Fragmentation; akinetes, aplanospore, and biflagellate zoospores; sexual reproduction unknown.

Key to the Species

1. Vegetative cells 5-10 x 8-30μ ---------- *M. stagnorum*
1. Vegetative cells 11-16 x 6-25μ ---------- *M. willeana*
1. Vegetative cells 14-18 x 14-40μ ---------- *M. floccosa*

1. *Microspora willeana* Lagerheim (Pl. 1, Fig. 8). Vegetative cells 11-16 x 6-25μ, walls thin; akinetes spherical or nearly so, 14-18μ in diameter; filaments cylindrical.

Haunck.

2. *Microspora floccosa* (Vaucher) Thuret (Pl. 1, Fig. 9). Vegetative cells 14-18 x 14-40μ, wall thin; akinetes variously shaped, 18-22μ in diameter; filaments cylindrical or nearly so.

East Harbor.

3. *Microspora stagnorum* (Kuetzing) Lagerheim (Pl. 1, Fig. 10). Vegetative cells (5-) 7-10 x 8-30μ, wall thin; aplanospores ellipsoid or spheroid.
Squaw.

Family *Cylindrocapsaceae*

CYLINDROCAPSA Reinsch 1867

Filaments unbranched, usually uniseriate within a pectic tubular envelope, cells sometimes irregularly arranged; vegetative cells ellipsoid, ovoid, subrectangular or spheroid, each with a stratified gelatinous wall; chloroplast massive, pyrenoid single.

Fragmentation; biflagellate zoospores; eggs and biflagellate sperms; oospores; *Palmella* stages.

Key to the Species

1. Vegetative cells globose, or nearly so ---------- *C. geminella*
1. Vegetative cells ellipsoid ---------- *C. geminella* v. *minor*

1. *Cylindrocapsa geminella* Wolle (Pl. 1, Fig. 19). Vegetative cells globose or nearly so, 14-24μ in diameter, with thick lamellate walls; oospore globose, 40-50μ in diameter, with lamellate wall 10-15μ thick.
Squaw, Haunck.

a. Var. *minor* Hansgirg (Pl. 1, Fig. 20). Vegetative cells 12-25 x 15-50μ, ellipsoid to cylindric; oospore globose, 18-25μ in diameter, not filling oogonium.
Pelee.

Family *Chaetophoraceae*

CHAETOPHORA Schrank 1789

Filaments branched, inclosed in a macroscopic, tough envelope that may be spherical, hemispherical, elongate, or irregularly tuberculate; fasciculate branching at the apices and ultimate branchlets often multicellularly setiferous; vegetative cells cylindrical or somewhat swollen; chloroplast single, covering whole wall in young cells and then with 1 pyrenoid, becoming zonate in larger cells with several pyrenoids.

Quadriflagellate zoospore; akinetes; biflagellate gametes; zygotes.

Key to the Species

1. Colony globose or tuberculate ---------- 2
1. Colony elongate, irregularly laciniate ---------- *Ch. incrassata*
2. Branching lax and spreading ---------- *Ch. elegans*
2. Branching erect ---------- *Ch. pisiformis*

1. *Chaetophora elegans* (Roth) Agardh (Pl. 2, Figs. 31, 32). Gelatinous colonies globose or subglobose; filaments with lax branching, radiating from center of colony; vegetative cells of main filaments 6-11 x 20-100μ.

Gibraltar, Haunck, Fisher, Quarry pools on Kelleys, mouth of Cold Creek.

2. *Chaetophora pisiformis* (Roth) Agardh (Pl. 2, Fig. 30). Gelatinous

colonies globose to tuberculate; filaments radiating from center of colony, branches with fasciculate and sometimes setiferous apices; vegetative cells of main filaments 5-8 x 15-40μ, cylindrical.

Gibraltar, Fisher.

3. *Chaetophora incrassata* (Hudson) Hazen (Pl. 3, Fig. 40). Gelatinous colonies elongate, irregularly lobed and laciniate; main filaments elongate, bearing densely fascicled and usually setiferous branchlets; vegetative cells of main filaments 8-16 x 8-90μ, cylindrical or swollen.

Quarry pools on Kelleys, Pelee, West Harbor, East Harbor.

Stigeoclonium Kuetzing 1843

Plant differentiated into an irregularly branched or somewhat parenchymatous prostrate system and a sparsely branched erect portion with obscure main axis and with lateral branches much attenuate; often inclosed in a delicate gelatinous sheath; vegetative cells cylindric or slightly swollen, uninucleate; chloroplast transversely zonate with several pyrenoids, or (in young cells) a complete girdle with one pyrenoid, or in setiferous cells none.

Fragmentation; *Palmella* stages; quadriflagellate zoospores; akinetes; aplanospores; biflagellate gametes (quadriflagellate in some species); zygotes.

Key to the Species

1. Erect portion of thallus branched ---------- 2
1. Erect portion of thallus unbranched ---------- *S. gracile*
2. Opposite branching predominating ---------- 3
2. Alternating branching predominating ---------- 4
3. Vegetative cells 5-10μ in diameter ---------- *S. tenure*
3. Vegetative cells 10-12μ in diameter ---------- *S. lubricum* v. *varians*
3. Vegetative cells 14-17μ in diameter ---------- *S. lubricum*
4. Vegetative cells 7-11μ in diameter ---------- *S. stagnatile*
4. Vegetative cells 12-18μ in diameter ---------- *S. subsecundum*

1. *Stigeoclonium tenue* (Agardh) Kuetzing (Pl. 3, Fig. 39). Vegetative cells 5-10 x 7-30μ; branches more often opposite, though some always solitary; tufts bright green.

Squaw, Smith, Kelleys, Gibraltar, Starve, Catawba; probably generally distributed along Lake Erie shores in spring.

2. *Stigeoclonium lubricum* (Dillwyn) Kuetzing (Pl. 2, Fig. 26). Vegetative cells 14-17 x 10-30μ, somewhat swollen; branching opposite or various.

Gibraltar, Squaw, Hen Island.

a. *Var.* varians (Hazen) Collins (Pl. 2, Fig. 25). Vegetative cells 10-12 x 20-60μ, with shorter tufts and more setiferous branches than the species.

Gibraltar.

3. *Stigeoclonium stagnatile* (Hazen) Collins (Pl. 2, Fig. 29). Vegetative cells 7-11 x 8-32μ; filaments sparsely branched, solitary or opposite; forming floccose masses.

Gibraltar.

4. *Stigeoclonium subsecundum* Kuetzing (Pl. 2, Fig. 27). Vegetative cells 12-18 x 13-150μ; branching sparse and solitary; tufts loose, pale green to yellowish.

West Harbor, Gibraltar.

5. *Stigeoclonium gracile* (W. & G. S. West) comb. nov. (=*Pseudochaete gracilis* W. & G. S. West 1903, p. 37; West 1904, p. 88, fig. 30; West & Fritsch 1927, p. 192, fig. 75; Smith 1933, p. 393, fig. 263) (Pl. 2, Fig. 28). Vegetative cells of prostrate part of thallus 5-8 x 5-12μ; cells of erect portion 1.5-3 x 20-400μ; erect branches tapering, sharp-pointed or not.

Hatchery Bay, Squaw; on submerged leaves of *Vallisneria*.

This alga may have a prostrate system either branched or unbranched (usually the latter) or sometimes roughly pseudoparenchymatous. In view of the ramification of plant habit in *Stigeoclonium*, it would appear that the genus *Pseudochaete* is of uncertain standing. I have therefore transferred *P. gracilis* to the former genus.

Draparnaldia Bory 1808

Filaments branched, attached by rhizoids, and inclosed in a soft gelatinous investment, with prostrate portion of plant not prominent; erect part of plant differentiated into large primary branches and smaller fasciculate branches, branchlets terminating in long hyaline setae; cells of primary branches cylindrical or swollen, with a transversely zonate chloroplast; chloroplasts of axial cells entire or reticulate, with several pyrenoids; cells of branches usually cylindrical with chloroplast covering entire wall and ordinarily with one pyrenoid.

Quadriflagellate zoospores; akinetes; quadriflagellate gametes; zygotes.

1. *Draparnaldia glomerata* (Vaucher) Agardh (Pl. 1, Fig. 21). Vegetative cells of main axis inflated, 50-125 x 30-200μ; filaments repeatedly branched, branchlets without a distinct main axis; chloroplast of cells of main axis narrowly zonate.

West Harbor.

Aphanochaete A. Braun 1851

Filaments simple or irregularly branched, prostrate on other algae; vegetative cells cylindrical, barrel-shaped, globose, or cylindric-globose, bearing one or more long hyaline setae from their dorsal sides; chloroplast laminate, parietal, usually with several pyrenoids.

Quadriflagellate zoospores; aplanospores; heterogamous, quadriflagellate gametes.

1. *Aphanochaete repens* A. Braun (Pl. 1, Fig. 18). Vegetative cells subglobose to cylindrical, 5-10 x 5-12μ; setae 3-4μ thick at base and up to 200μ long, sometimes absent.

Squaw.

Family *Protococcaceae*

PROTOCOCCUS Agardh 1824

Cells solitary or in clumps of few cells, rounded or ellipsoid or angularly compressed, wall thick; chloroplast parietal, laminate, usually without pyrenoids; aerial on stones, sticks, and tree trunks.

Cell division; no other reproduction known.

1. *Protococcus viridis* Agardh (Pl. 1, Figs. 22-24). Vegetative cells 4-10 x 4-12μ.

All islands: on barks of trees and occasionally on wood of docks and piers; never normally aquatic.

Whether the common greenish incrustation on tree trunks should be called *Protococcus viridis* Agardh or *Pleurococcus vulgaris* Meneghini, algologists are still in disagreement. West and Fritsch (1927) and Fritsch (1934) adopt the latter name, while G. M. Smith (1933) uses the former. These authors should be consulted regarding the historical aspects of the various appellations in vogue at different titmes. If one follows the Cambridge Congress of 1930 in stipulating type species, it is clear that *Protococcus* is the proper generic name.

Family *Coleochaetaceae*

COLEOCHAETE de Brébisson 1844

Filamentous, irregularly branched, erect and prostrate or prostrate only and then with branches distinct or laterally joined into a parenchymatous disc, epiphytic or endophytic; some cells with single, lone, unbranched setae basally ensheathed by a gelatinous cylinder; cells uninucleate with a single laminate chloroplast usually with one pyrenoid.

Biflagellate zoospores; aplanospores; sperms and eggs; thickwalled oospore.

Key to the Species

1. Plant a more or less flat plate or disc ---------- 2
1. Plant not plate-like or disc-like ---------- *C. irregularis*
2. Filaments united laterally ---------- 3
2. Filaments not united laterally ---------- *C. soluta*
3. Vegetative cells 8-16 x 16-30μ ---------- *C. orbicularis*
3. Vegetative cells 25-45 x 25-120μ ---------- *C. scutata*

1. *Coleochaete irregularis* Pringsheim (Pl. 1, Fig. 12). Vegetative cells 18-25 x 18-40μ, quadrangular or polygonal; filaments irregularly branched, free or somewhat united, prostrate or nearly erect; oogonia ovoid, 60-100 x 60-120μ, naked or corticate.

Squaw. On leaves of *Nymphaea* and *Potamogeton*.

2. *Coleochaete orbicularis* Pringsheim (Pl. 1, Fig. 11). Vegetative cells 8-16 x 16-30μ, oblong to polygonal; filaments laterally united into a parenchymatous monostromatic frond; oogonia ovoid, 50-66 x 60-86μ.

East Harbor.

3. *Coleochaete scutata* Brébisson (Pl. 1, Fig. 13). Vegetative cells 25-45 x 25-120μ, quadrangular; filaments laterally united into a parenchymatous disc and radiating from the center; oogonia sublgobose, 120-140 x 140-160μ, corticate.

Squaw, East Harbor. On leaves of submerged aquatics.

4. *Coleochaete soluta* (Brébisson) Pringsheim (Pl. 1, Fig. 14). Vegetative cells 12-25 x 25-100μ; filaments radiating from a common center, prostrate, not laterally united; oogonia corticate, usually globose, up to 200μ in diameter; antheridia flask-shaped, 17-20 x 25-30μ.

East Harbor. Epiphytic on submerged parts of *Sagittaria* leaves.

Chaetosphaeridium Klebahn 1892

Unicellular or in dense clumps or roughly filamentous, with or without a gelatinous envelope, epiphytic on other algae; vegetative cells ovoid to spherical, each bearing distally a long seta basally ensheathed, uninucleate; chloroplast one or two, laminate and parietal.

Cell division; zoospores. Sexual reproduction not known.

1. *Chaetosphaeridium pringsheimii* Klebahn (Pl. 1, Fig. 17). Vegetative cells 9-12 x 9-14μ, united by persistent utricles; sheaths 2 x 13-18μ; setae up to 300μ long.

Squaw, Terwilliger's.

Suborder *Cladophorineae*
Family *Cladophoraceae*
Cladophora Kuetzing 1843

Filaments usually with profuse lateral branching, attached by well-defined rhizoidal cells; vegetative cells with thick stratified walls, multinucleate, much longer than broad; chloroplasts single and reticulate or numerous and discoid, pyrenoids several.

Quadriflagellate zoospores; biflagellate gametes; most species with alternation of diploid asexual with a haploid sexual generation.

1. *Cladophora glomerata* (Linnaeus) Kuetzing. (Pl. 3, Fig. 36). Vegetative cells 35-100 x 120-700μ; filaments densely branched; both sexual and asexual generations diploid, reduction division taking place just prior to gamete formation.

General distribution on rocks, stones, wood, and other substrata, sometimes accidentally free-floating.

This species is very variable in form and appearance and perhaps all the specimens in the region are referable to it. Plants that resemble *C. fracta* (Dillwyn) Kuetzing and *C. crispata* (Roth) Kuetzing have been collected at intervals.

Rhizoclonium Kuetzing 1843

Filaments with short rhizoidal branches one- to few-celled, sometimes unbranched, with holdfasts; vegetative cells with thick and stratified walls, multinucleate; chloroplast parietal, reticulate, with several pyrenoids.

Fragmentation; irregularly shaped vegetative cells resembling akinetes; biflagellate zoospores.

Key to the Species

1. Vegetative cells 10-25μ in diameter ---------- *R. hieroglyphicum*
1. Vegetative cells 50-90μ in diameter ---------- *R. hookeri*

1. *Rhizoclonium hieroglyphicum* (Agardh) Kuetzing (Pl. 2, Figs. 33, 34). Vegetative cells 10-25 x 20-125μ, branches one-celled or none.
Terwilliger's, Haunck, Fisher, East Harbor, Pelee, Wehrle.

2. *Rhizoclonium hookeri* Kuetzing (Pl. 2, Fig. 35). Vegetative cells 50-90 x 100-350μ, branches usually pluricellular.
Terwilliger's, Fisher.

Basicladia Hoffmann and Tilden 1930

Filaments branched, sometimes only in region of holdfast cells, attached to freshwater turtles by rhizoidal outgrowths or by a coralloid system of prostrate branches; erect filaments with shorter cells toward apex; vegetative cells multinucleate, chloroplast somewhat massive or scarcely reticulate, with pyrenoids.
Zoospores or gametes from shortened cells of filament.

Key to the Species

1. Erect filaments 12-50μ in diameter ---------- *B. chelonum*
1. Erect filaments 50-125μ in diameter ---------- *B. crassa*

1. *Basicladia chelonum* (Collins) Hoffmann and Tilden (Pl. 4, Figs. 46-49). Vegetative cells 12-50 x 25-500μ; sporangia 30-50 x 30-200μ; basal coenocyte up to 1000μ long; branches usually in vicinity of holdfast cells.
Haunck, Smith. Shell of living *Chrysemys marginata* Agassiz.

2. *Basicladia crassa* Hoffman & Tilden (Pl. 4, Figs. 50-53). Vegetative cells (40-) 50-125 x 40-700μ; sporangia 64-127 x 87-180μ; basal coenocyte 40-120 x 1000-3175μ; branches common, short or long, those of the basal coenocyte dichotomous but not common.
Smith. On shell of living *Graptemys geographica* (Le Sueur).

B. crassa has previously been reported only from St. Peter, Minnesota, by Hoffman. It was collected by him from shell of living *Chelydra serpentina* (Linnaeus).

Pithophora Wittrock 1877

Similar to *Cladophora* except often not as freely branched and cell walls not as evidently lamellated; large terminal or intercalary akinetes, solitary or in series.
Fragmentation; akinetes.

1. *Pithophora varia* Wille (Pl. 3, Figs. 37, 38). Vegetative cells 50-100 x 100-500μ; akinetes ovoid, cylindrical or irregular, 60-112 x 70-250μ.
Fisher, Haunck, Wehrle.

Order *Oedogoniales*
Family *Oedogoniaceae*
OEDOGONIUM Link 1820

Filaments single, unbranched; vegetative cells cylindrical, or sometimes capitellate, nodulose or undulate; chloroplast parietal and usually reticulate, with one or more pyrenoids; basal cell with holdfast; terminal cell obtuse, apiculate, or hyaline; all vegetative cells, except the basal one, capable of division.

Multiciliate zoospores; multiciliate sperms and non-motile eggs; monoecious or dioecious; if dioecious, antheridial filaments the same size as oogonial (macrandrous) or much smaller and known as dwarf males (nannandrous); dwarf males produced from androspores formed in androsporangia; oospores germinating usually into 4 multiciliate zoospores.

Key to the Species

1. Vegetative cells 3-7μ in diameter ---------- 2
1. Vegetative cells 7-56μ in diameter ---------- 5
2. Oospore medianly constricted ---------- *Oe. pusillum*
2. Oospore not medianly constricted ---------- 3
3. Vegetative cells capitellate ---------- *Oe. capitellatum*
3. Vegetative cells not capitellate ---------- 4
4. Oogonium globose ore nearly so ---------- *Oe. inconspicuum*
4. Oogonium oblong ---------- *Oe. gracillimum*
5. Monoecious ---------- 6
5. Dioecious ---------- 8
6. Vegetative cells 6-9μ in diameter ---------- *Oe. capitellatum*
6. Vegetative cells 10-16μ in diameter ---------- 7
6. Vegetative cells 16-24μ in diameter ---------- *Oe. eriense*
6. Vegetative cells 37-48μ in diameter ---------- *Oe. geniculatum*
7. Ooogonium opening by a pore ---------- *Oe. varians*
7. Oogonium opening by a lid ---------- *Oe. crispum*
8. Oogonium scarcely exceeding vegetative cells in diameter ---------- 9
8. Oogonium noticeably exceeding vegetative cells in diameter ---------- 10
9. Oospore globose to cylindric-globose ---------- *Oe. capillare*
9. Oospore cylindric-globose to subcylindric ---------- *Oe. capillare* f. *stagnale*
10. Wall of oospore smooth ---------- 11
10. Wall of oospore longitudinally costate ---------- 20
10. Wall of oospore echinate ---------- *Oe. echinospermum*
10. Wall of oospore scrobiculate ---------- 22
11. With dwarf males ---------- *Oe. idioandrosporum*
11. Without dwarf males ---------- 12
12. Oogonium poriferous ---------- 13
12. Oogonium operculate ---------- 17
13. Vegetative cells 12-16μ in diameter ---------- *Oe. varians*
13. Vegetative cells 20-27μ in diameter ---------- 14
13. Vegetative cells 28-52μ in diameter ---------- 15
14. Oogonium 36-42μ in diameter ---------- *Oe. gracilius*
14. Oogonium 42-49μ in diameter ---------- *Oe. plagiostomum*
15. Oospore globose, 47-65μ long ---------- *Oe. princeps*
15. Oospore ovoid, 60-102μ long ---------- 16
15. Oospore ellipsoid, 100-125μ long ---------- *Oe. longum*
16. Oogonium 49-60μ in diameter ---------- *Oe. grande*
16. Oogonium 63-78μ in diameter ---------- *Oe. landsboroughi*
17. Oogonium with median operculum ---------- *Oe. howardii*
17. Oogonium with superior operculum ---------- 18
17. Oogonium with basal operculum ---------- 19

18. Female vegetative cell 10-15μ in diameter---*Oe. pringsheimii* v. *nordstedtii*
18. Female vegtative cell 14-20μ in diameter---*Oe pringsheimii*
19. Oogonium 27-37 x 22-30μ ---*Oe. howei*
19. Oogonium 40-48 x 41-50μ ---*Oe. infimum*
20. Costae on median wall of oospore ---21
20. Costae on outer wall of oospore ---*Oe. exocostatum*
21. Costae distinctly crenulate ---*Oe. crenulatocostatum*
21. Costae scarcely crenulate---*Oe. crenulatocostatum* v. *cylindricum*
22. Oogonium 23-33μ in diameter ---*Oe. moniliforme*
22. Oogonium 38-45μ in diameter ---*Oe punctatum*
22. Oogonium 52-64μ in diameter ---*Oe. wyliei*

1. *Oedogonium capillare* (Linnaeus) Kuetzing (Pl. 6, Figs.. 88-89) Dioecious, macrandrous; oogonium 1, not or scarcely exceeding the vegetative cell in diameter, cylindrical to subcylindrical, pore superior; oospore globose to cylindric-globose to ovoid, not or completely filling oogonium, spore wall smooth; antheridium 1—4, often alternating with vegetative cell; sperms 2, division horizontal; basal cell elongate; terminal cell broadly apiculate to obtuse; female vegetative cell 35-56 x 36-120μ, male 35-50 x 35-90μ; oogonium 40-60 x 45-75μ; oospore 30-52 x 35-65μ; antheridium 30-48 x 5-10μ.

Generally distributed.

a. F. *stagnale* (Kuetzing) Hirn (Pl. 6, Fig. 90). Oospore subcylindrical or cylindrical-globose, sometimes constricted at the middle, not filling oogonium; female vegetative cell 38-50 x 40-100μ, male 35-45 x 36-90μ; oogonium 40-60 x 55-75μ; oospore 36-57 x 40-60μ; antheridium 33-42 x 5-9μ.

Gibraltar.

2. *Oedogonium howardii* G. S. West (Pl. 7, Figs. 93, 94). Dioecious, macrandrous; oogonium single or in groups of two, globose or subglobose, operculate, division median and wide; oospore globose, filling oogonium, wall smooth; antheridia up to 16-celled, sperm single; vegetative cell evidently capitellate; basal cell hemispherical or nearly spherical; vegetative cell 7-12 x 18-42μ; oogonium 26-33 x (23-) 26-33μ; oospore 21-30 x 24-30μ; antheridium 7-9 x 5-14μ; basal cell 12-20 x 10-13μ.

Fisher, Haunck, East Harbor, mouth of Toussaint River.

3. *Oedogonium crenulatocostatum* Wittrock (Pl. 7, Figs. 98, 99). Dioecious, macrandrous; oogonium 1-6, obovoid to subellipsoid, often terminal, pore superior; oospore of the same form as the oogonium, which it nearly or quite fills, outer spore wall smooth, median wall with 14-20 longitudinal ribs, crenulate and sometimes anastomosing, inner wall smooth; antheridium 2-6, often alternating with vegetative cell; sperms 2, division horizontal; terminal cell obtuse to broadly apiculate; female vegetative cell 10-18 x 25-125μ, male 9-13 x 32-80μ; oogonium 30-36 x 40-65μ; oospore 28-34 x 37-55μ; antheridium 9-12 x 9-14μ.

East Harbor, Gibraltar.

a. Var. *cylindricum* (Hirn) Tiffany (Pl. 7, Fig. 100). Oogonium and oospore cylindric-oblong or more rarely ellipsoid or obovoid-ellipsoid; ribs of oospore scarcely crenulate; vegetative cell 11-16 x 44-150μ; oogonium 30-36 x 42-81μ; oospore 27-34 x 40 65μ.

East Harbor, Haunck.

4. *Oedogonium crispum* (Hassall) Wittrock (Pl. 7, Fig. 97). Monoecious; oogonium usually 1, obovoid-globose, operculate, division superior; oospore globose or subglobose, quite filling the oogonium, spore wall smooth; antheridium 1-5, subepigynous or hypogynous; sperms 2, division horizontal; basal cell elongate, terminal cell apically obtuse; vegetative cell (10-) 12-16 x 35-80μ; oogonium 37-45 x 41-53μ; oospore 35-43 x 37-43μ; antheridium 8-14 x 7-12μ.

Haunck.

5. *Oedogonium exocostatum* Tiffany (Pl. 7, Figs. 101-105). Dioecious, macrandrous, oogonium 1-2, ellipsoid to ellipsoid-globose, occasionally terminal, pore superior; oospore of the same form as the oogonium, which it very nearly completely fills, spore wall of two layers: the outer marked by 13-15 longitudinal ribs, inner smooth; suffultory cell swollen; male filament a little more slender than the female, antheridium 3-7; sperms 2, division horizontal; basal cell elongate; female vegetative cell (13-) 18-25 x 72-140μ, male (13-) 16-20 x 48-100μ; suffultory cell 22-30 x 60-90μ; oogonium 40-52 x 60-96μ; oospore 38-41 x 56-68μ; antheridium 12-16 x 7-12μ.

Gibraltar, Haunck.

6. *Oedogonium geniculatum* Hirn (Pl. 9, Fig. 127). Monoecious; oogonium 1, obovoid or obovoid-globose, pore superior; oospore globose or subdepressed globose, not filling oogonium, spore wall smooth and thick; antheridium 1-5, subepigynous or subhypogynous or scattered, sometimes alternating with vegetative cells; sperms (?) 2, division (?) horizontal; vegetative cell 37-48 x 60-135μ; oogonium 56-63 x 56-68μ; oospore 48-59 x 48-59μ; antheridium 37-44 x 5-9μ.

7. *Oedogonium gracilius* (Wittrock) Tiffany (Pl. 6, Figs. 82, 83). Dioecious, macrandrous; oogonium 1, obovoid-globose, with superior pore; oospore globose to subglobose, usually filling ogonium, spore wall smooth; antheridium 1-8, often alternating with vegetative cell; basal cell elongate; vegetative cell 20-25 x 40-100μ; oogonium 36-42 x 46-57μ; oospore 34-39 x 36-44μ; antheridium 19-22 x 7-10μ.

Terwilliger's, Sugar Island.

8. *Oedogonium gracillimum* Wittrock & Lundell (Pl. 9, Fig. 132). Monoecious; oogonium 1, oblong, operculate, division superior; oospore oblong-ellipsoid, not filling oogonium, spore wall smooth; antheridium 1; sperms 2, division horizontal; basal cell elongate; vegetative cell 4-7 x 16-42μ; oogonium 14-19 x 34-40μ; oospore 13-17 x 24-32μ; antheridium 3-5 x 4-7μ.

East Harbor, Wehrle, Hatchery.

9. *Oedogonium grande* Kuetzing (Pl. 6, Figs. 85-87). Dioecious, macrandrous; oogonium 1-5, subobovoid, pore superior; oospore of the same form as oogonium, which it completely fills or not, spore wall smooth; antheridium 1-10; sperms 2, division vertical; basal cell elongate; female vegetative cell 28-37 x 70-210μ, male 28-33 x 70-175μ; oogonium 49-60 x 86-110μ; oospore 47-58 x 60-94μ; antheridium 25-33 x 11-18μ.

Squaw, Gibraltar, Haunck, Fisher, Wehrle.

10. *Oedogonium idioandrosporum* (Nordstedt & Wittrock) Tiffany (Pl. 7, Figs. 91, 92). Dioecious, nannandrous, idioandrosporous; oogonium 1-3, globose-obovoid to globose, pore superior; oospore ellipsoid-globose, ovoid, or angular-globose (rarely globose), nearly filling the oogonium, spore wall smooth and thick; androsporangium 1-4; dwarf male straight or slightly curved, on or near the suffultory cell; antheridium exterior, 1 or 2; vegetative cell 25-36 x 65-200μ; oogonium 48-59 x 57-90μ; oospore 42-57 x 50-66μ; androsporangium 30-34 x 12-21μ; dwarf male stipe 14-16 x 60-70μ; antheridium 8-10 x 10-18μ.

Haunck.

11. *Oedogonium inconspicuum* Hirn (Pl. 9, Figs. 133, 134, 139). (?) Dioecious, (?) macrandrous, oogonium 1-4, depressed- or subpyriform globose, operculate, division narrow and median; oospore degressed-globose or ovoid, filling the inflated part of oogonium, spore wall smooth; vegetative cell 3-5 x 20-34μ; oogonium 13-18 x (13-) 17-23μ; oospore 12-17 x 8-13μ; basal cell 16-18 x 7-8μ.

Pelee, Hatchery.

12. *Oedogonium landsboroughi* (Hassall) Wittrock (Pl. 6, Figs 78, 79). Dioecious, macrandrous; oogonium 1-2, (rarely 3), obovoid to ovoid, pore superior; oospore ovoid to ellipsoid, filling or not filling the oogonium, spore wall smooth; antheridium up to 30-seriate; sperms two, division vertical; basal cell elongate; terminal cell obtuse; female vegetative cell 31-40 x 90-240μ, male 30-37 x 120-225μ; oogonium 63-78 x 85-115μ; oospore (55-) 59-70 x 73-102μ; antheridium 27-35 x 9-20μ.

Haunck.

13. *Oedogonium plagiostomum* Wittrock (Pl. 6, Fig. 84). Dioecious, macrandrous; oogonium 1, obovoid-globose, with superior pore; oospore globose to subglobose, usually filling ogonium, spore wall smooth and thickened; antheridium 1-6, often alternating with vegetative cell; basal cell elongate; vegetative cell 22-27 x 65-120μ; oogonium 42-49 x 50-60μ; oospore 41-47 x 42-49μ; antheridium 20-24 x 8-10μ.

Terwilliger's.

14. *Oedogonium princeps* (Hassall) Wittrock (Pl. 6. Figs. 80-81; Pl. 8, Fig. 120). Dioecious, macrandrous; oogonium 1, slightly tumid, subobovoid, pore superior; oospore globose or subglobose, not filling oogonium, spore wall smooth; terminal cell apiculate; antheridium 1-7; vegetative cell 33-43 x 40-155μ; oogonium 51-63 x 54-80μ; oospore 48-58 x 47-65μ; antheridium 32-38 x 5-20μ.

Pelee Point.

15. *Oedogonium pringsheimii* Cramer (Pl. 8, Figs. 116, 117). Dioecious, macrandrous; oogonium 1-6, subovoid-globose, operculate, division superior; oospore globose, nearly filling oogonium, spore wall smooth, often thickened; antheridium to 10-seriate, often alternating with vegetative cell; sperms 2, division horizontal; basal cell elongate; terminal cell broadly apiculate or

obtuse; female vegetative cell 14-20 x 28-100μ, male 12-16 x 24-64μ; oogonium 35-43 x 36-46μ; oospore 30-37 x 30-37μ; antheridium 10-15 x 6-9μ.
Haunk, Gibraltar.

a. Var. *nordstedtii* Wittrock (Pl. 8, Figs. 114, 115). Smaller than the type, oogonium 1-2, oospore not filling oogonium; female vegetative cell 10-16 x 20-76μ, male 9-15 x 18-68μ; oogonium 28-39 x 36-45μ; oospore 26-34 x 27-34μ; antheridium 9-12 x 8-9μ.
Gibraltar.

16. *Oedogonium pusillum* Kirchner (Pl. 9, Fig. 140). Monoecious; oogonium 1 (rarely 2), subbiconic-ellipsoid or subbiconic-globose, seen from above circular, margin even, operculate, division wide (usually up to 2.5μ); oospore ellipsoid or globose, generally constricted at the middle, not quite filling oogonium, spore wall smooth; antheridium 1 or 2, subepigynous, sperm (?) 1; basal cell subhemispherical; terminal cell obtuse or obtusely conical; vegetative cell 3-6 x 10-60μ; oogonium 14-16 x 15-25μ; oospore 11-13 x 13-15μ; antheridium 3-4 x 5-6μ; basal cell 7-8 x 7-8μ.
Pelee.

17. *Oedogonium varians* Wittrock and Lundell (Pl. 7, Figs. 95, 96). Monoecious, (or sometimes dioecious); oogonium 1, or rarely more, depressed- or subdepressed-pyriform-globose, pore nearly superior; oospore globose, not filling oognium, spore wall smooth; antheridium to 9-seriate, scattered; sperms 2, division horizontal; basal cell elongate; terminal cell apically obtuse; vegetative cell 12-16 x 35-144μ; oogonium 34-50 x 34-55μ; oospore 31-41 x 30-41μ; antheridium 11-15 x 5-7μ.
Squaw, Haunck, Gibraltar.

18. *Oedogonium capitellatum* Wittrock (Pl. 8, Figs. 118, 119). Monoecious; oogonium 1, subdepressed- or depressed-globose, operculate, division median; oospore depressed-globose completing oogonium, or nearly so, walls smooth; antheridium 1-3, subepigynous or hypogynous or rarely scattered, sperm 1; basal cell subhemispherical or broadly ellipsoid; terminal cell piliform; vegetative cells capitellate, 6-9 x 20-60μ, oogonium 20-26 x 17-23μ; oospore 18-23 x 15-19μ; antheridium 6-7 x 5-9μ; basal cell 16-18 x 6-10μ.
Squaw, Hatchery Bay.

19. *Oedogonium infimum* Tiffany (Pl. 8, Figs. 110-113). Dioecious, macrandrous; oogonium 1, globose or subglobose, with basal operculum; oospore globose or subglobose, walls smooth; antheridium 1-10, sperms 2; vegetative cells distinctly capitellate; basal cell subhemispherical; vegetative cell 12-20 x 60-140μ; oogonium 40-48 x 41-50μ; oospore 40-44 x 38-42μ; antheridium 14-20 x 8-12μ; basal cell 30-42 x 16-24μ.

Hatchery Bay. Incrusted with calcium carbonate and growing on leaves of *Vallisneria*. Previously known only from Iowa.

20. *Oedogonium howei* Tiffany (Pl 8, Figs. 125, 126). Dioecious, mac-

randrous; oogonium 1, depressed-globose or globose (rarely subglobose), with basal operculum; oospore similar in form to oogonium and filling it, walls smooth; antheridia 1-20 (if single, often alternating with vegetative cells), sperms (?)1; vegetative cell capitellate; basal cell hemispherical or depressed-globose; vegetative cell 8-17 x 21-78μ; oogonium 27-37 x 22-30μ; oospore 25-35 x 20-27μ; antheridium 9-11 x 8-14μ; basal cell 16-23 x 13-16μ.

Hatchery Bay. Much incrusted with calcium carbonate; growing on *Vallisneria* leaves. Previously reported only from Puerto Rico.

Oe. infimum and *Oe. howei* are similar in being dioecious and in being basally operculate. They are easily differentiated on the basis of size.

21. *Oedogonium echinospermum* A. Braun (Pl. 9, Figs. 137, 138). Dioecious, nannandrous, gynandrosporous or idioandrosporous; oogonium 1, ellipsoid-globose or subglobose, pore median; oospore globose, quite filling oogonium, outer layer of spore wall echinate; androsporangium 1-5, dwarf male curved or not, on suffultory cell, antheridium exterior, 1-2; vegetative cell 18-30 x 45-130μ; oogonium 39-50 x 41-57μ; oospore (with spines) 38-47 x 38-49μ; androsporangium 21-25 x 9-15μ; dwarf male stipe 10-15 x 26-35μ; antheridium 6-12 x 6-15μ.

East Harbor.

22. *Oedogonium moniliforme* Wittrock (Pl. 9, Figs. 135, 136). Dioecious, macrandrous; oogonium 1-5, pyriform to globose-ovoid, pore supramedian (sometimes nearly superior); oospore globose or subdepressed-globose, not filling oogonium, at least longitudinally, middle layer of oospore wall scrobiculate; terminal cell apically obtuse; antheridium 1-5; vegetative cell 9-13 x 30-72μ; oogonium 23-33 x 28-42μ; oospore 22-32 x 22-32μ; antheridium 10-12 x 8-13μ.

East Harbor. This species, originally described by Wittrock from Sweden, has previously been reported for the United States from Michigan and Ohio. This is the first collection in which antheridial filaments have been observed, and they furnish the data for an emended description (Tiffany, 1936a).

23. *Oedogonium longum* Transeau (Pl. 8, Figs. 123, 124). Dioecious, macrandrous; oogonium 1, ellipsoid, pore superior; oospore ellipsoid to elongate-ellipsoid, not filling oogonium longitudinally, walls smooth; antheridium 1-5, sperms 2, division vertical; female vegetative cell 40-52 x 100-240μ, male 36-44 x 100-180μ; oogonium 68-84 x 120-180μ; oospore 66-80 x 100-125μ; antheridium 34-40 x 8-14μ.

Haunck. Previously reported for New York. It occurs, however, in the writer's collections from both Indiana and Puerto Rico.

24. *Oedogonium eriense* Tiffany (Pl. 8, Figs. 121, 122). Monoecious; oogonium ellipsoid to broadly ellipsoid, with superior operculum; oospore broadly ellipsoid to ovoid, not filling oogonium longitudinally, with outer and inner walls smooth and median wall longitudinally ribbed: the ribs 18-26 in number; antheridium 1-?, subepigynous, sperm (?) single; vegetative cell 16-24 x 52-104μ; oogonium 38-48 x 64-85μ; oospore 36-46 x 48-70μ; antheridium 16-19 x 15-16μ.

Haunck. This species bears some resemblance to the poriferous *Oe. boscii* (Le Cl.) Wittr. and *Oe paludosum* (Hass.) Wittr. It is smaller than the macrandrous *Oe. paucostriatum* Tiffany and *Oe. paucocostatum* Transeau. It is nearest in size to the dioecious *Oe. costatosporum* Jao. The small size, the monoecious habit, the longitudinal ribs, and the superior operculum are the differentiating characteristics of the species.

25. *Oedogonium wyliei* Tiffany (Pl. 7, Figs. 106-109). Dioecious, macrandrous; oogonium 1-4, globose to ovoid, pore superior; oospore globose to ovoid, filling or not filling oogonium, outer spore wall irregularly scrobiculate; antheridium 1-4, sperms 2, division horizontal; basal cell elongate; terminal cell, often an oogonium, apically obtuse or broadly apiculate; vegetative cell 16-24 x 80-170μ; oogonium 52-64 x 68-112μ; oospore 48-60 x 52-64μ; antheridium 16-19 x 8-18μ.

Gibraltar, Haunck, East Harbor.

26. *Oedogonium punctatum* Wittrock. Dioecious, macrandrous; oogonium 1-4, obovoid (rarely globose-obovoid), pore superior; oospore obovoid, nearly filling oogonium (rarely subglobose and not filling oogonium) outer spore wall scrobiculate; antheridium 1-5, often alternating with vegetative cell; sperms 2, division horizontal; basal cell elongate; terminal cell (often an oogonium) apically obtuse; vegetative cell 15-22 x 42-128; oogonium 38-45 x 52-65μ; oospore 37-43 x 43 55μ; antheridium 15-17 x 6-10μ.

Haunck.

Bulbochaete Agardh 1817

Filaments usually attached, branched, the branches unilateral; vegetative cells normally widening upwards; basal cell ordinarily the only one capable of division in formation of main axis, first new cell forming a long tubular bristle with swollen bulb-like base, subsequent cells intercalated between basal cell and next one above; rarely division is intercalary; terminal cell of each branch always furnished with a bristle.

Reproduction as in *Oedogonium*, except that no dioecious macrandrous species are known.

Key to the Species

1. Vegetative cells rectangular in appearance ---------- *B. rectangularis*
1. Vegetative cells not rectangular in appearance ---------- 2
2. Oogonium globose or subglobose ---------- 3
2. Oogonium ovoid or ellipsoid ---------- 4
3. Ooospore wall smooth to scrobiculate ---------- *B. intermedia*
3. Oospore wall scrobiculate to nearly crenulate ---------- *B. crenulata*
4. With dwarf males ---------- 5
4. Without dwarf males ---------- 6
5. Oogonium 26-30 x 39-46μ ---------- *B. varians* v. *subsimplex*
5. Oogonium 30-36 x 44-54μ ---------- *B. varians*
6. Diameter of oogonium 20-25μ ---------- *B. nana*
6. Diameter of oogonium 28-34μ ---------- *B. robusta*

1. *Bulbochaete rectangularis* Wittrock (Pl. 9, Fig. 130). Dioecious, nannandrous, gynandrosporous; oogonia ellipsoid, patent or more rarely erect,

below terminal setae or androsporangia or more rarely vegetative cells; outer oospore wall longitudinally ribbed; androsporangia scattered or epigynous, 1-?; dwarf males near or occasionally on oogonia; antheridia exterior, 1-4; vegetative cells, subrectangular in cross section, 16-23 x 20-46μ; oogonia 32-39 x 45-63μ; oospores 29-37 x 43-61μ; androsporangia 13-16 x 10-27μ; dwarf male stipes 14-18 x 22-27μ; antheridia 8-10 x 5-7μ.

Hatchery Bay, Squaw.

2. *Bulbochaete varians* Wittrock (Pl. 9, Fig. 143). Dioecious, nannandrous, gynandrosporous; oogonia ovoid, patent or erect, below terminal setae or below androsporangial cells; outer oospore wall longitudinally ribbed, ribs serrate; androsporangia scattered, epigynous or hypogynous, 1-2; dwarf males on or near the oogonia, antheridia exterior, 1-3; vegetative cells 17-22 x 22-33μ; oogonia 30-36x 44-54μ; oospores 28-34 x 42-52μ; androsporangial cells 14-17 x 14-18μ; dwarf male stipes 14-16 x 24-27μ; antheridial cells 8-10 x 6-7μ.

Hatchery Bay, Squaw.

a. Var. *subsimplex* (Wittrock) Hirn. (Pl. 9, Fig. 131). Smaller in nearly all parts; ribs of oospore serrulate or smooth; vegetative cells 13-18 x 16-34μ; oogonia 26-30 x 39-46μ; oospores 24-28 x 37-44μ; androsporangial cells 10-14 x 7-16μ; dwarf male stipes 11-14 x 15-24μ; antheridial cells 7-8 x 5-7μ.

Squaw.

3. *Bulbochaete intermedia* DeBary (Pl. 9, Fig. 141). Dioecious, nannandrous, gynandrosporous; oogonia subdepressed-globose, patent, below androsporangia; division of suffultory cells nearly median; outer wall of oospore scrobiculate, rarely apparently smooth; androsporangia 1-2, epigynous or rarely scattered; dwarf males on the oogonium; antheridium interior, stipe slightly curved, shorter than the antheridium; vegetative cells 17-20 x 35-70μ; oogonia 40-48 x 31-40μ; oospores 38-46 x 30-38μ; androsporangial cells 11-13 x 7-12μ; dwarf males 9-10 x 21-26μ.

East Harbor.

4. *Bulbochaete crenulata* Pringsheim (Pl. 9, Fig. 142). Dioecious, nannandrous, gynandrosporous; oogonia subdepressed-globose, patent, below terminal setae or androsporangia, or rarely vegetative cells; division of suffultory cells median or slightly below; spore wall scrobiculate to crenulate; androsporangia epigynous or scattered, 1-5; dwarf males on or near oogonia, antheridia interior, stipe slightly curved, shorter than antheridium; vegetative cells 16-20 x 32-70μ; oogonia 43-48 x 35-43μ; oospores 40-46 x 33-40μ; antheridia 10-15 x 7-10μ; dwarf males 9-10 x 24-26μ.

East Harbor.

The last two species are undoubtedly closely related, but in a collection containing ample fruiting material the markings on the oospore wall are quite distinct (Tiffany, 1930).

5. *Bulbochaete nana* Wittrock (Pl. 9, Fig. 144) Monoecious; oogonia

ellipsoid, patent, below terminal setae or vegetative cells; outer wall of oospore longitudinally ribbed; antheridia 1-2, erect or rarely patent, subepigynous or scattered; vegetative cells 10-17 x 10-27μ; oogonia 20-25 x 33-40μ; oospores 18-23 x 30-38μ; antheridia 7-9 x 5-9μ.

Gibraltar. Previously unreported for the United States outside of Alaska.

6. *Bulbochaete robusta* (Hirn) Tiffany. Monoecious; vegetative cell often nearly globose; oogonium broadly ellipsoid, usually patent, below terminal seta or vegetative cell; outer wall of oospore longitudinally costate; antheridium 1-2, erect or patent, subepigynous or scattered; vegetative cell 14-23 x 14-27μ; oogonium 28-34 x 39-45μ; oospore 26-32 x 37-42μ; antheridium 8-10 x 5-8μ.

Kennedy Pond on Kelleys.

Order *Ulvales*
Family *Schizomeridaceae*
SCHIZOMERIS Kuetzing 1843

Filamentous; uniseriate with apical cell somewhat acuminate and with holdfast cell when young; older filaments solid cylinders of brick-like cells; filaments cylindrical or constricted at intervals; cells with ring-like transverse walls, sometimes not extending to the surface; chloroplast band-like or massive with several pyrenoids or several chloroplasts each with a pyrenoid.

Fragmentation; quadriflagellate zoospores; aplanospores; gametes.

1. *Schizomeris leibleinii* Kuetzing (Pl. 1, Figs. 15, 16). Vegetative cells 10-30 x 10-50μ, rounded or angular; older filaments up to 150μ in diameter and 10-20 centimeters long.

Quarry pool on Kelleys.

Order *Siphonales*
Family *Vaucheriaceae*
VAUCHERIA De Candolle 1803

Filaments coenocytic, sparsely or numerously branched, multi-nucleate, aquatic or terrestrial, often attached by rhizoids; sometimes forming densely tufted, velvety masses; chloroplasts numerous, small, discoid and rather peripherally located in the protoplasm, each with a pyrenoid, or pyrenoids absent; nuclei minute.

Multiflagellate zoospores; aplanospores; eggs and sperms (homothallic).

Key to the Species

1. Oogonium sessile on main filament ---------- *V. sessilis*
1. Oogonium on end of branch ---------- 2
2. Oogonia usually 2-6 in groups ---------- *V. geminata*
2. Oogonia usually solitary ---------- 3
3. Oogonia sessile on branch, or nearly so ---------- *V. terrestris*
3. Oogonia stipitate ---------- *V. hamata*

1. *Vaucheria sessilis* (Vaucher) De Candolle (Pl. 3, Fig. 43). Filaments 50-130μ in diameter; oogonia usually two, sometimes single, sessile or on very

short stalks, ovoid or oblong-ovoid, 70-85 x 75-100μ, more or less oblique, with short beak; antheridium between the two oogonia or beside the single oogonium, on a short pedicel, straight, hooked or circinate; mature oospore dark-spotted, with triple membrane, filling oogonium; zoosporangium ovoid-clavate, terminal, producing a single zoospore 77-154 x 82-176μ.

On moist soil, edge of Fox Marsh, Pelee

2. *Vaucheria geminata* (Vaucher) De Candolle (Pl. 3, Fig. 42). Filaments 29-130μ in diameter; oogonia one to six, 52-225 x 64-190μ, ellipsoid-hemispherical to convex-concave, shortly stipitate near the end of a short branch; antheridium cylindrical, hooked or circinate, usually on a stipe longer than those of the oogonia; mature oospore brown-spotted with triple membrane, filling oogonium; aplanospores 120-200 x 120-190μ, in ovoid sporangia usually terminating short lateral branches; thick-walled cells ("akinetes").

Haunck.

3. *Vaucheria terrestris* (Vaucher) De Candolle (Pl. 3, Fig. 44). Filaments 43-100μ in diameter; oogonium usually solitary, 85-125 x 60-100μ, lateral on a short branch containing at its summit a curved or circinate antheridium 18-24μ in diameter; oospore globose to plano-convex, with four membranes and numerous brown spots.

East Harbor, Pelee.

4. *Vaucheria hamata* (Vaucher) De Candolle (Pl. 3, Fig. 41). Filaments 38-80μ in diameter; oogonium solitary or two, 75-90 x 60-75μ, ovoid to convex-concave, borne on the shorter division of the apparently forking branch, the longer division recurved, bearing the hooked or circinate antheridium; if two oogonia, the antheridium between; oospore with four membranes, filling oogonium, with a dark brown or blackish central spot.

Pelee.

The material from Fox Marsh, Pelee Island, seems definitely to intergrade between *V. hamata* and *V. terrestris*. I have given the descriptions of both above, but the Pelee material might fit either one. Both *V. orthocarpa* Reinsch and *V. uncinata* Kuetz. have been collected from overflow pools of Cold Creek near Venice, Ohio.

Dichotomosiphon Ernst 1902

Dichotomously branched, coenocytic filaments, transversely constricted at each dichotomy and less commonly between branches, with colorless rhizoids; chloroplast numerous, lens-shaped, without pyrenoids but with starch accumulation.

Tuberous akinetes; biflagellate sperms and eggs in antheridia and oogonia.

1. *Dichotomosiphon tuberosus* (A. Braun) Ernst (Pl. 3, Fig. 45). Filaments 40-110μ in diameter and up to 10 centimeters long; akinetes straight and elongate or clavate and curved, 200-400 x 500-5000μ; antheridia and oogonia at the ends of ultimate branches; antheridia 35-50 x 130-170μ;

oogonia globose, 290-320μ in diameter; oospore of same shape, dark green, 250-280μ in diameter.

Pelee.

Order *Zygnematales*
Family *Zygnemataceae*[4]
Zygnema Agardh 1824

Simple filaments with cylindric cells; chloroplasts 2 (rarely 1-4), stellate, each with a central pyrenoid, connected by a cytoplasmic isthmus containing the nucleus; filaments sometimes with prominent gelatinous sheaths; conjugation usually scalariform, sometimes lateral; zygotes formed in conjugating tube or in one of the gametangia.

Fragmentation; aplanospores and parthenospores; zygotes of various shapes and colors and with walls variously ornamented or smooth.

Key to the Species

1. Wall of zygote smooth ---------- *Z. insigne*
1. Wall of zygote punctate or scrobiculate ---------- 2
2. Receptive gametangium cylindric, or nearly so ---------- *Z. cruciatum*
2. Receptive gametangium inflated ---------- 3
3. Vegetative cells 24-28 x 50-180μ ---------- *Z. vaucherii*
3. Vegetative cells 28-38 x 27-100μ ---------- *Z. stellinum*

1. *Zygnema insigne* (Hassall) Kuetzing (Pl. 4, Fig. 54). Vegetative cells 26-32 x 26-60μ; zygote, in one of the gametangia, globose or subglobose, 27-33 x 27-35μ, median wall brown and smooth.

East Harbor.

2. *Zygnema cruciatum* (Vaucher) Agardh (Pl. 4, Fig. 57). Vegetative cells 30-35 x 30-60μ; zygote, in one of the gametangia, globose to ovoid, 30-38 x 32-40μ, median spore wall brown and scrobiculate with pits 1.5-2μ in diameter.

Wehrle.

3. *Zygnema vaucherii* Agardh (Pl. 4, Fig. 55). Vegetative cells 24-28 x 50-180μ; zygote, in one of the gametangia, ovoid, 24-36 x 26-45μ, median spore wall brown and scrobiculate, pits about 3μ in diameter.

East Harbor.

4. *Zygnema stellinum* (Vaucher) Agardh (Pl. 4, Fig. 56). Vegetative cells 28-38 x 27-100μ; zygote in one of the gametangia; zygote ovoid, 30-42 x 35-48μ, median spore wall yellow-brown and scrobiculate, with pits 3-4μ in diameter and 3-4μ apart.

Terwilliger's, Squaw.

Mougeotia Agardh 1824

Filaments simple or rarely with one-or two-celled branches, rhizoids common, with cylindric cells; chloroplasts 1 or 2 axile plates with several pyre-

4 For much of the descriptive matter pertaining to the species in the genera of the Zygnemataceae, the writer is indebted to Professor Transeau (1926, 1934, as well as unpublished data).

noids; pyrenoids in a single row or irregularly distributed; zygotes usually formed in the conjugating tubes, cytoplasmic residues remaining in the gametangia.

Fragmentation; aplanospores; zygotes of various shapes and colors and with walls variously ornamented or not.

Key to the Species

1. Diameter of vegetative cells 3.5-4.5μ ---------- *M. elegantula*
1. Diameter of vegetative cells 8-20μ ---------- 2
1. Diameter of vegetative cells 20-24μ ---------- *M. sphaerocarpa*
1. Diameter of vegetative cells 25-38μ ---------- *M. genuflexa*
2. Zygote blue, with peripheral pectic layer ---------- *M. cyanea*
2. Zygote brown, without peripheral pectic layer ---------- 3
3. Sporangium adjoined by three cells ---------- *M. notabilis*
3. Sporangium adjoined by two cells ---------- *M. nummuloides*

1. *Mougeotia elegantula* Wittrock (Pl. 4, Fig. 58). Vegetative cells 3.5-4.5 x 50-135μ; chloroplast with 4-8 pyrenoids; conjugating cells geniculate, sporangium adjoined by 4 cells; zygote cruciate-quadrate, 18-24μ in diameter, with smooth walls and rounded corners.

Quarry pool on Kelleys.

2. *Mougeotia genuflexa* (Dillwyn) Agardh (Pl. 4, Fig. 61). Vegetative cells 25-38 x 50-225μ, often geniculate and not forming zygotes; conjugation lateral or scalariform; sporangium adjoined by 2 cells; zygote quadrate-ovoid to globoid, 30-40μ in diameter, wall brown and smooth.

Fisher, Haunck, East Harbor, West Harbor.

3. *Mougeotia cyanea* Transeau (Pl. 4, Fig. 62). Vegetative cells (14-) 16-18 (-20) x 160-200μ, chloroplast occupying less than one half of the cell and with 4-10 pyrenoids; zygote with long axis parallel to the filament, compressed-spheroid, 30-40 x 38-48μ; aplanospores spheroidal, 30-32μ in diameter; both zygotes and aplanospores blue with finely punctate wall and with peripheral pectic layer 4-8μ thick.

Quarry pools on Kelleys.

4. *Mougeotia notabilis* Hassall (Pl. 4, Fig. 59). Vegetative cells 10-18 x 50-250μ, sporangium usually adjoined by 3 cells; zygotes subglobose to nearly ovoid, 24-28 x 26-36μ; aplanospores obliquely ovoid to trapezoid, 16-20 x 25-30μ; spore walls smooth.

Gibraltar; mouth of Cold Creek (Venice).

5. *Mougeotia nummuloides* (Hassall) De Toni (Pl. 4, Fig. 60). Vegetative cells 8-16 x 32-160μ, sporangium adojoined by 2 cells, chloroplast with 4 pyrenoids; zygote globoid to ovoid, 17-37μ (usually 22-32μ) in diameter, median wall brown and scrobiculate; aplanospore similar.

Quarry pools on Kelleys.

6. *Mougeotia sphaerocarpa* Wolle (Pl. 4, Fig. 62A). Vegetative cells 19-24 x 60-240μ, usually with 4-6 pyrenoids; zygote in greatly enlarged conjugating tube or extending into one of the gametangia, ovoid to subglobose

36-40 x 40-55μ, wall smooth and brown; aplanospore ovoid to obliquely ovoid, 24-30 x 35-50μ.

Haunck.

Spirogyra Link 1820

Filaments simple, with cylindric cells; chloroplasts 1-16 straight or spirally arranged ribbons with several to many pyrenoids; nucleus centrally placed and supported by cytoplasmic strands; zygote in one of the gametangia.

Fragmentation; aplanospores; akinetes, parthenospores; zygote formed by lateral or scalariform conjugation and of various shapes with walls variously ornamented or smooth; conjugation tube formed by both gametangia or almost entirely by the male cell only.

Key to the Species

1. Vegetative cells with 1 (sometimes 2) chloroplast ---- 2
1. Vegetative cells with 3-12 chloroplasts ---- 9
2. Cells with plane end walls ---- 3
2. Cells with replicate end walls[5] ---- 6
3. Median wall of zygote finely punctate ---- *S. lagerheimii*
3. Median wall of zygote smooth ---- 4
4. Fertile cells cylindric or enlarged ---- 5
4. Fertile cells inflated ---- *S. varians*
5. Zygotes usually ellipsoid ---- *S. juergensii*
5. Zygotes usually ovoid ---- *S. longata*
6. Vegetative cells 8-12μ in diameter ---- *S. tenuissima*
6. Vegetative cells 19-34μ in diameter ---- 7
7. Zygote with scrobiculate wall ---- *S. protecta*
7. Zygote with smooth wall ---- 8
8. Fertile cells cylindrically inflated ---- *S. quadrata*
8. Fertile cells slightly enlarged ---- *S. weberi*
9. Vegetative cells 35-45μ in diameter ---- *S. fluviatilis*
9. Vegetative cells 50-80μ in diameter ---- 10
9. Vegetative cells 86-115μ in diameter ---- *S. setiformis*
9. Vegetative cells 125-165μ in diameter ---- 11
10. Zygote lenticular; cholorplasts nearly straight ---- *S. majuscula*
10. Zygote ovoid; chloroplasts making 1-2.5 turns ---- *S. neglecta*
11. Zygote compressed-ovoid; 140-160μ long ---- *S. crassa*
11. Zygote compressed-ellipsoid, 160-220μ long ---- *S. crassoidea*
11. Zygote ellipsoid, 160-225μ long ---- *S. ellipsospora*

1. *Spirogyra crassa* Kuetzing (Pl. 5, Fig. 63). Vegetative cells 140-165 x 126-330μ, with plane end walls; chloroplasts 6-12 making 0.5-1 turn; fertile cells cylindric or rarely enlarged; zygote compressed-ovoid, 120-150 x 140-160 x 80-100μ, median wall smooth and brown.

Fisher, Pelee.

2. *Spirogyra crassoidea* Transeau. (=*S. ellipsospora* Transeau var. *crassoidea* Transeau 1914, p. 295). (Pl. 5, Fig. 77). Vegetative cells 140-150 x 140-560μ, with plane end walls; chloroplasts 3-8 making 0.5 to 4 turns; zygote compressed-ellipsoid, usually with rounded ends, 120-140 x 145-220μ, median wall smooth and yellowish-brown.

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5 Some of the cells may have plane end walls, but if any cell is replicate, the species is so considered.

Fisher, East Harbor, Catawba.

3. *Spirogyra ellipsospora* Transeau (Pl. 5, Fig. 72). Vegetative cells 125-150 x 125-500μ, with plane end walls; chloroplasts 3-8, making 0.4-5 turns; fertile cells cylindrical; zygote ellipsoid, more or less pointed, 100-140 x 160-255μ, median wall smooth and yellow-brown.

Fisher, East Harbor.

4. *Spirogyra fluviatilis* Hilse (Pl. 5, Fig. 67). Vegetative cells 35-45 x 70-240μ, with plane end walls; chloroplasts 3-4, making 1.5-3.5 turns; fertile cells shortened and inflated; zygote ovoid, 57-65 x 68-110μ, with median wall scrobiculate and brown.

Squaw, Hatchery, Terwilliger.

5. *Spirogyra juergensii* Kuetzing (Pl. 5, Fig. 73). Vegetative cells 24-30 x 60-125μ, with plane end walls; chloroplast 1, making 2-4 turns; zygote and aplanospore ellipsoid, 29-33 x 50-75μ, median wall yellow and smoth.

West Harbor.

6. *Spirogyra lagerheimii* Wittrock (Pl.5, Fig. 71). Vegetative cells 25-33 x 75-150μ, with plane end walls; chloroplast 1, making 0.5-4 turns; fertile cells cylindric or enlarged; zygote ellipsoid, 25-38 x 50-100μ, median wall yellowish-brown and finely punctate.

Cedar Point.

7. *Spirogyra majuscula* Kuetzing (Pl. 5, Fig. 74). Vegetative cells 50-80 x 80-500μ, with plane end walls; chloroplasts 3-8, straight or making about 0.3 turn; fertile cells shortened, cylindric or inflated; zygote lenticular, 57-72μ in diameter, 45-60μ in thickness, median spore wall brown and smooth.

Fisher, Smith, East Harbor, Catawba, Kelleys (quarry pool), Pelee, Pelee Point.

8. *Spirogyra neglecta* (Hassall) Kuetzing (Pl. 5, Fig. 65). Vegetative cells 55-67 x 100-300μ, with plane end walls; chloroplasts 3, making 1-2.5 turns; fertile cells enlarged or inflated; zygote and aplanospore ovoid, 54-64 x 75-100μ, median wall smooth and yellow.

Terwilliger's.

9. *Spirogyra protecta* Wood (Pl. 5, Fig. 76). Vegetative cells 28-34 x x 120-425μ, with replicate end walls; chloroplast 1 or rarely 2 chloroplasts, making 2-6 turns; fertile cells cylindric or slightly enlarged; zygote ovoid to cylindric-ovoid, 30-38 x 66-90μ, outer wall of 2 layers: the inner scrobiculate and the outer smooth, median wall smooth and yellow.

East Harbor.

10. *Spirogyra quadrata* (Hassall) Petit (Pl. 5, Fig. 69). Vegetative cells 24-30 x 70-300μ, with replicate end walls; chloroplast 1, making 1.5-6 turns; fertile cells cylindrically inflated, with the middle up to 60μ; zygote and aplanospore ellipsoid to cylindric-ellipsoid, 33-44 x 50-78μ, median wall smooth and brown.

Manila Bay (North Bass).

11. *Spirogyra setiformis* (Roth) Kuetzing (Pl. 5, Fig. 75). Vegetative cells 86-115 x 100-225μ, with plane end walls; chloroplasts 4, making 0.5-1 turn; fertile cells cylindric; zygote ellipsoid, 85-100 x 115-160μ, median wall smooth and brown.

Fisher.

12. *Spirogyra tenuissima* (Hassall) Kuetzing (Pl. 5, Fig. 70). Vegetative cells 8-12 x 40-250μ, with replicate end walls; chloroplast 1, making 3-6 turns; fertile cells enlarged or inflated; zygote and aplanospore ellipsoid, 25-32 x 40-70μ, median wall smooth and yellow.

Squaw, Terwilliger's.

13. *Spirogyra varians* (Hassall) Kuetzing (Pl. 5, Fig. 64). Vegetative cells 30-40 x 30-120μ, with plane end walls; chloroplast 1, making 1-5 turns; fertile cells inflated, usually on the conjugating side only; sterile cells often greatly inflated; zygote ellipsoid (more rarely ovoid or globose), 32-40 x 50-100μ, median wall yellow and smooth.

Haunck, Terwilliger's.

14. *Spirogyra weberi* Kuetzing (Pl. 5, Fig. 66). Vegetative cells 19-30 x 80-480μ, with replicate end walls; chloroplast 1, making 3-6.5 turns; fertile cells slightly enlarged; zygote ovoid to cylindric-ovoid, 21-29 x 30-96μ, median wall smooth and yellow.

Haunck, Terwilliger's, Hatchery.

15. *Spirogyra longata* (Vaucher) Kuetzing (Pl. 9, Figs. 128, 129). Vegetative cells 26-38 x 45-280μ, with plane end walls; chloroplast 1, making 2-5 turns; fertile cells cylindric or enlarged by the spores; zygote ovoid or sometimes ellipsoid with rounded ends, 28-38 x 50-83μ, median wall smooth and yellow.

East Harbor.

Sirogonium Kuetzing 1843

Filaments simple, with cylindric cells; chloroplasts 2-9, straight or slightly spiral; conjugation direct, between short genuflexed cells of different filaments; vegetative cells similar to those of *Spirogyra*.

Fragmentation; zygotes formed in one of the gametangia.

1. *Sirogonium sticticum* (Engl. Bot.) Kuetzing (Pl. 5, Fig. 68). Vegetative cells 38-56 x 80-300μ, with plane end walls; chloroplasts 3-5, nearly straight or making 0.3 turn; conjugation direct, gametangia usually shortened and somewhat reflexed; zygote ellipsoid (rarely somewhat ovoid), 41-67 x 68-127μ, median wall smooth and yellow.

Haunck, East Harbor, quarry pool on Kelleys.

Class Myxophyceae [6]
Order *Hormogonales*
Suborder *Homocystineae*

[6] For descriptions and figures of species of Myxophyceae, see Tiffnay (1934).

Family *Oscillatoriaceae*
Lyngbya C. Agardh 1824

Key to the Species

1. Cells less than 3μ in diameter, plants contorted ---- *L. contorta*
1. Cells more than 3μ in diameter ---- 2
   2. Apex of trichome tapering and capitate ---- 3
   2. Apex of trichome neither tapering nor capitate ---- 4
3. Sheath colored, especially in older plants ---- *L. aestuarii*
3. Sheath colorless ---- *L. major*
   4. Cells usually less than 23μ in diameter ---- *L. birgei*
   4. Cells usually more than 23μ in diameter ---- *L. majuscula*

Oscillatoria Vaucher 1803

Key to the Species

1. Cells 2-3μ in diameter ---- *O. splendida*
1. Cells 3-60μ in diameter ---- 2
   2. Cells generally with pseudovacuoles ---- 3
   2. Cells without pseudovacuoles ---- 4
3. Trichomes usually joined laterally ---- *O. lacustris*
3. Trichomes not joined laterally ---- *O. prolifica*
   4. Apex of trichome tapering ---- 5
   4. Apex of trichome cylindric ---- 6
5. Filaments constricted at cross walls ---- *O. chalybea*
5. Filaments not constricted at cross walls ---- *O. agardhii*
   6. Slight constriction at cross walls ---- *O. tenuis*
   6. No constriction at cross walls ---- 7
7. Granules usually prominent at cross walls ---- *O. limosa*
7. Granules not prominent at cross walls ---- *O. princeps*

Phormidium Kuetzing 1843

Key to the Species

1. Apex of trichome capitate ---- *P. subfuscum*
1. Apex of trichome not capitate ---- *P. retzii*

Spirulina Turpin 1827

Key to the Species

1. Cells less than 1μ in diameter ---- *S. laxissima*
1. Cells more than 1μ in diameter ---- 2
   2. Spirals 2-4μ broad ---- *S. major*
   2. Spirals 8-16μ broad ---- *S. princeps*

Suborder *Heterocystineae*
Family *Nostocaceae*
Anabaena Bory 1822

Key to the Species

1. Vegetative cells 4-8μ in diameter ---- 2
1. Vegetative cells 8-16μ in diameter ---- 6
   2. Filaments straight or nearly so ---- 3
   2. Filaments not straight ---- 4
3. Vegetative cells spherical ---- *A. affinis*
3. Vegetative cells barrel-shaped ---- *A. catenula*
   4. Akinetes in mass at center of colony ---- *A. lemmermanni*
   4. Akinetes not in mass at center of colony ---- 5

5. Trichomes coiled or twisted ---------- *A. flosaquae*
5. Trichomes not coiled or twisted, sometimes bent ---------- *A. catenula*
6. Akinetes spherical or nearly so ---------- *A. planctonica*
6. Akinetes cylindric or ovoid ---------- 7
7. Akinetes 16-20μ in diameter ---------- 8
7. Akinetes 20-25μ in diameter ---------- *A. spiroides* v. *crassa*
8. Trichomes usually twisted ---------- *A. circinalis*
8. Trichomes usually straight ---------- *A. macrospora* v. *robusta*

NOSTOC Vaucher 1803

Key to the Species

1. Trichomes loosely entangled ---------- *N. pruniforme*
1. Trichomes densely entangled ---------- *N. coeruleum*

ANABAENOPIS Woloszynska; emend. Miller 1923

Key to the Species

1. Vegetative cells practically isodiametric ---------- *A. arnoldii*
1. Vegetative cells longer than broad ---------- *A. circularis*

APHANIZOMENON Morren 1838

One species: *Aphanizomenon flosaquae* (Linnaeus) Ralfs

CYLINDROSPERMUM Kuetzing 1843

One species: *Cylindrospermum stagnale* (Kuetzing) Bornet & Flahault

NODULARIA Mertens 1822

Key to the Species

1. Vegetative cells 4-6μ in diameter ---------- *N. harveyana*
1. Vegetative cells 6-12μ in diameter ---------- 2
2. Akinetes 7-10μ in diameter ---------- *N. sphaerocarpa*
2. Akinetes 12-15μ in diameter ---------- *N. spumigena*

Family *Scytonemataceae*

TOLYPOTHRIX Kuetzing 1843

Key to the Species

1. Vegetative cells 5-8μ in diameter ---------- *T. tenuis*
1. Vegetative cells 9-12μ in diameter ---------- *T. distorta*

Family *Rivulariaceae*

GLOEOTRICHIA J. Agardh 1842

Key to the Species

1. Akinetes 8-10μ in diameter ---------- *G. echinulata*
1. Akinetes 10-18μ in diameter ---------- 2
2. Vegetative cells 4-7μ in diameter ---------- *G. pisum*
2. Vegetative cells 7-9μ in diameter ---------- *G. natans*

Class HETEROPHYCEAE (XANTHOPHYCEAE)

Order *Heterotrichales*

Family *Tribonemaceae*

TRIBONEMA Derbes & Solier 1856

Key to the Species[7]

1. Vegetative cells 3-6μ in diameter ---------- 2
1. Vegetative cells 6-11μ in diameter ---------- *T. bombycinum*
1. Vegetative cells 11-17μ in diameter ---------- *T. utriculosum*
2. Cells with numerous chloroplasts ---------- *T. bombycinum* v. *tenue*
2. Cells with 2-4 chloroplasts ---------- *T. minus*

[7] For descriptions and figures of the species of *Tribonema*, see Tiffany (1934).

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DEPARTMENT OF BOTANY,
NORTHWESTERN UNIVERSITY,
EVANSTON, ILL.

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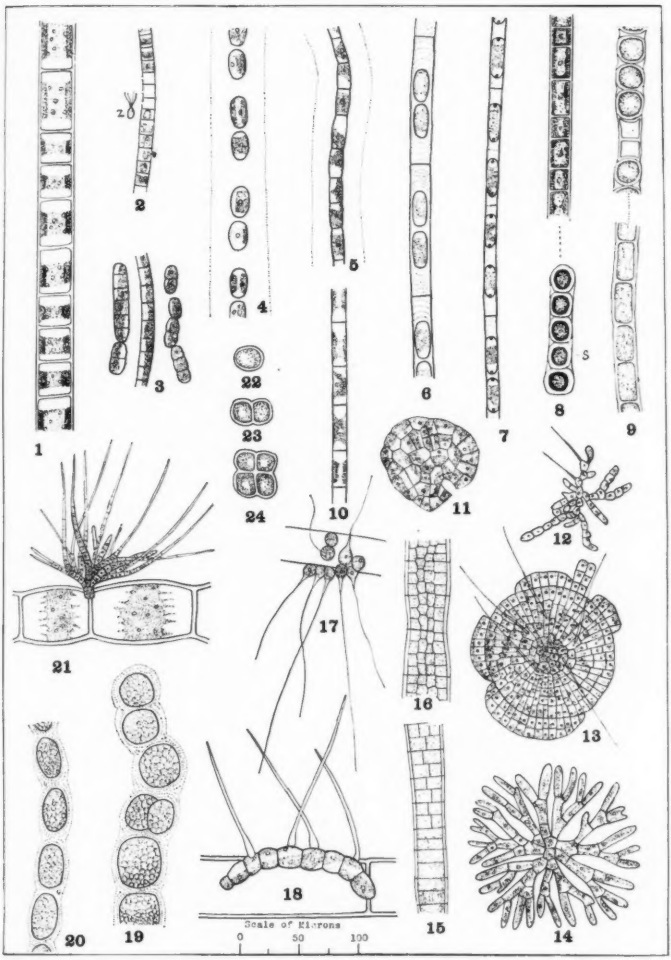

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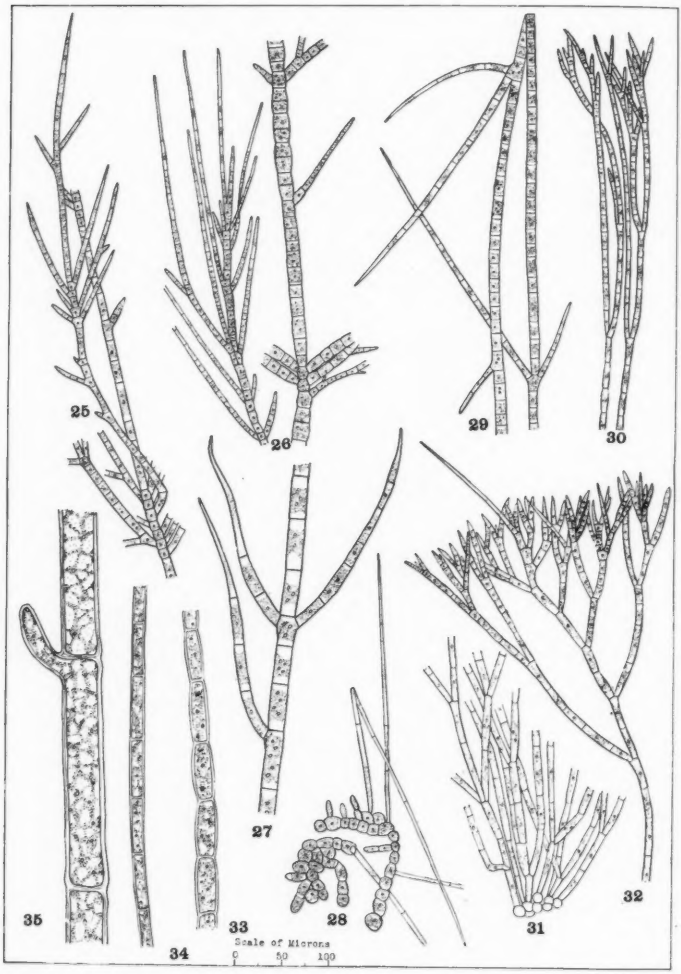

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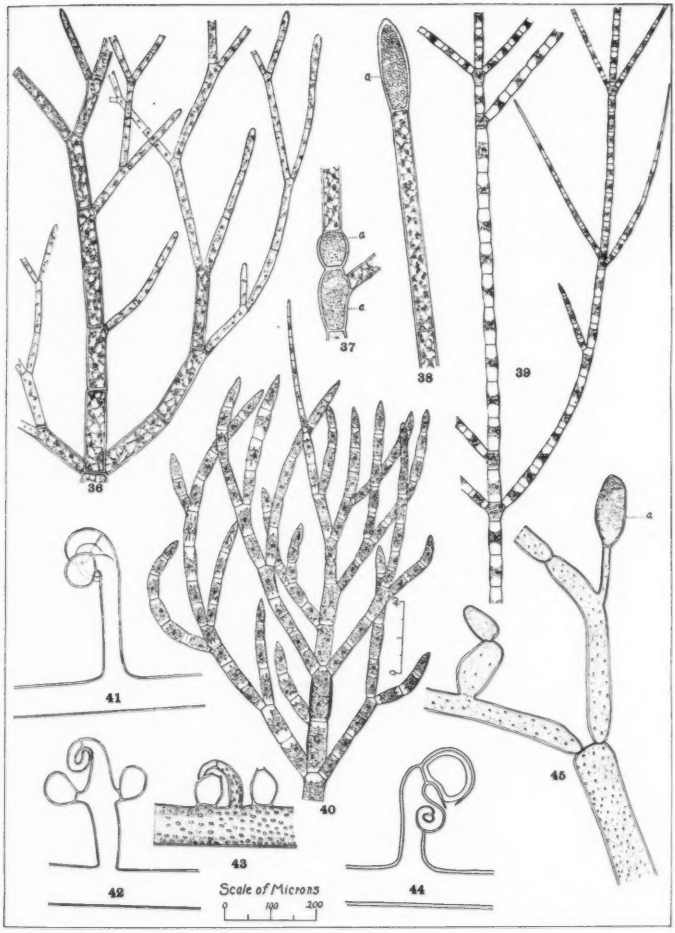

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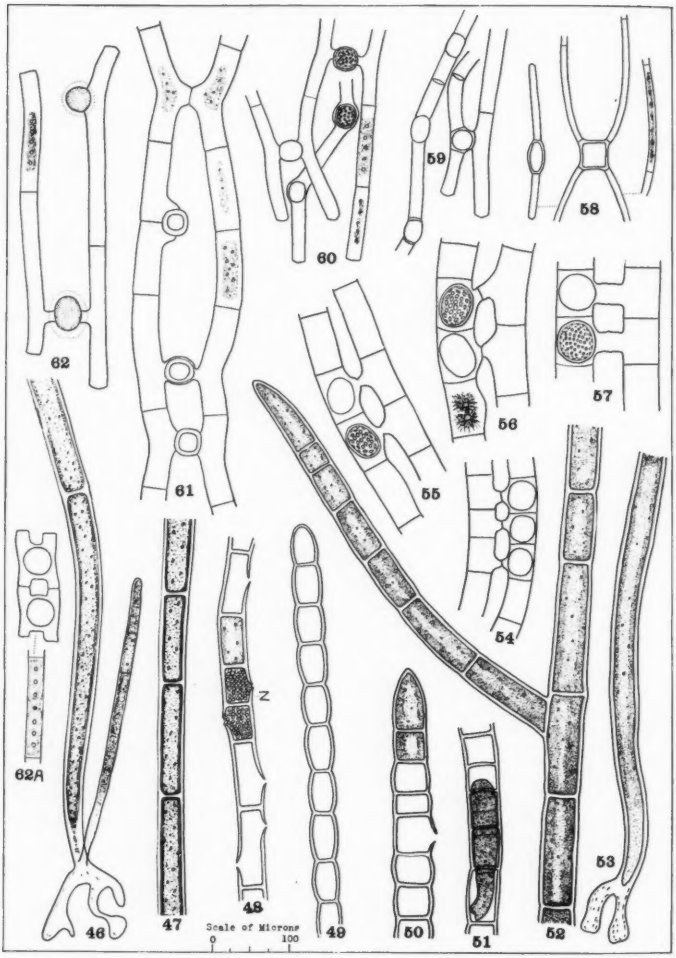

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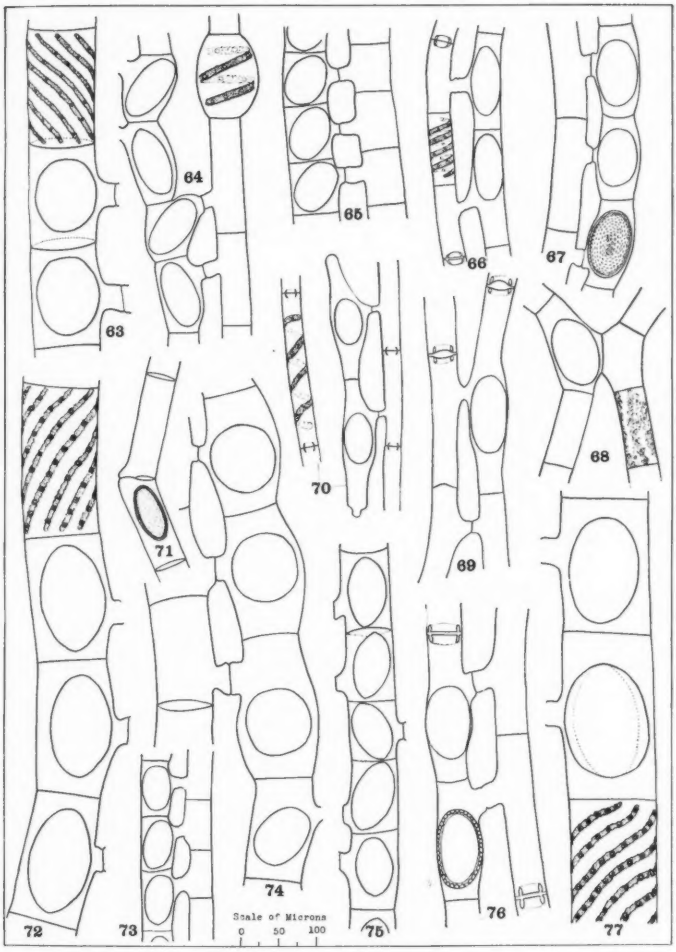

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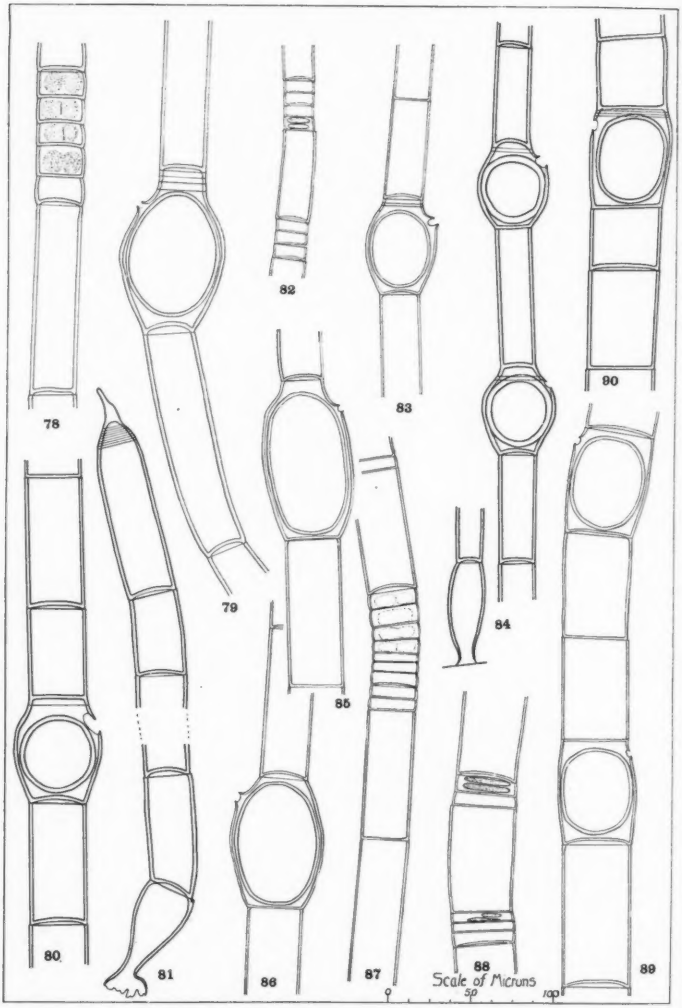

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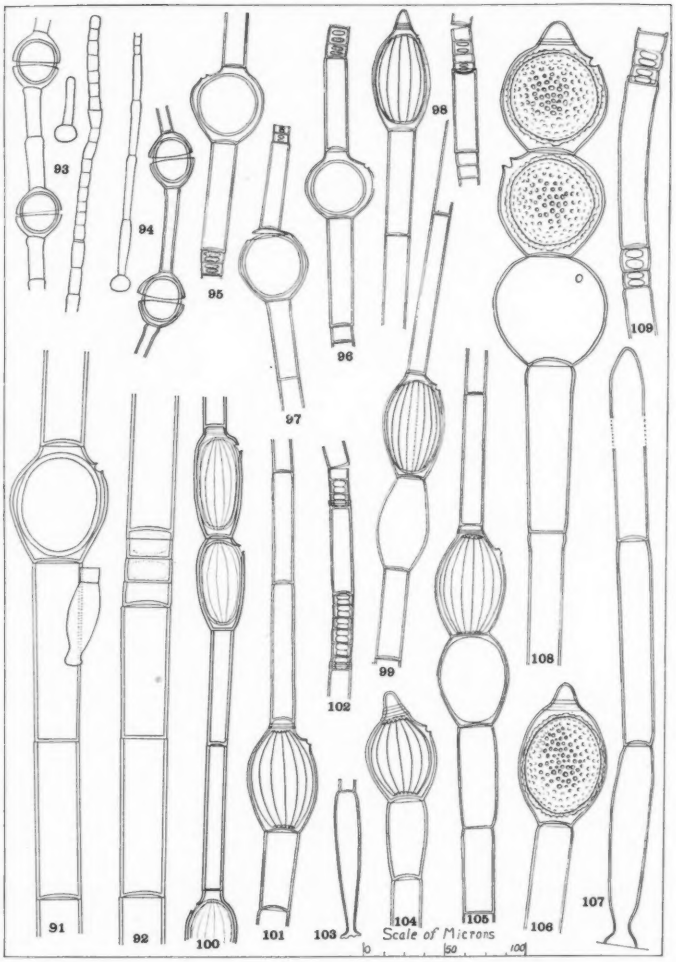

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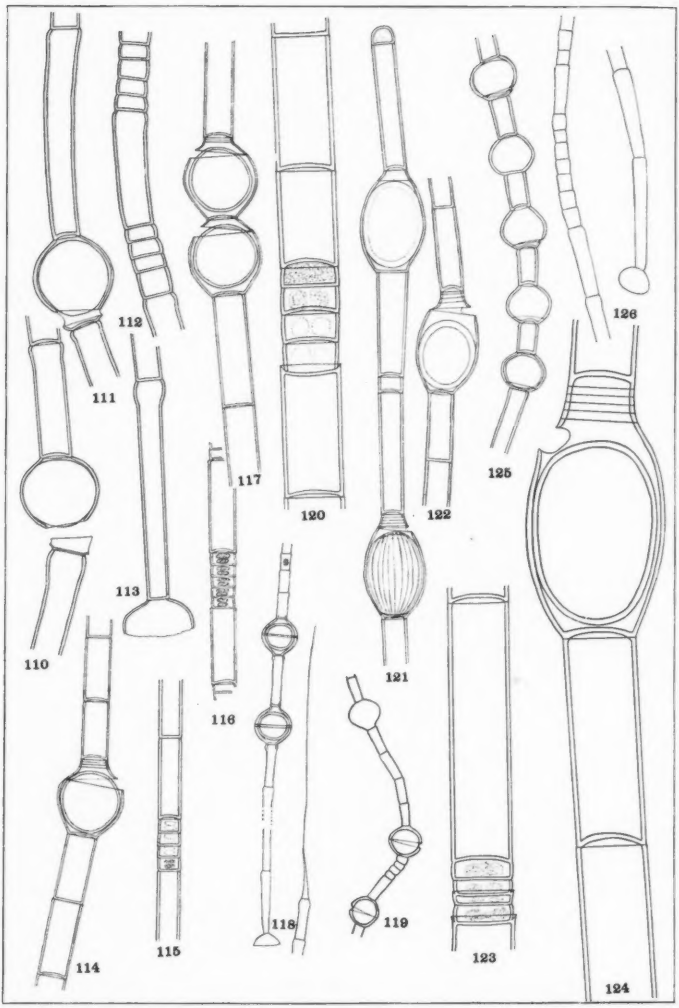

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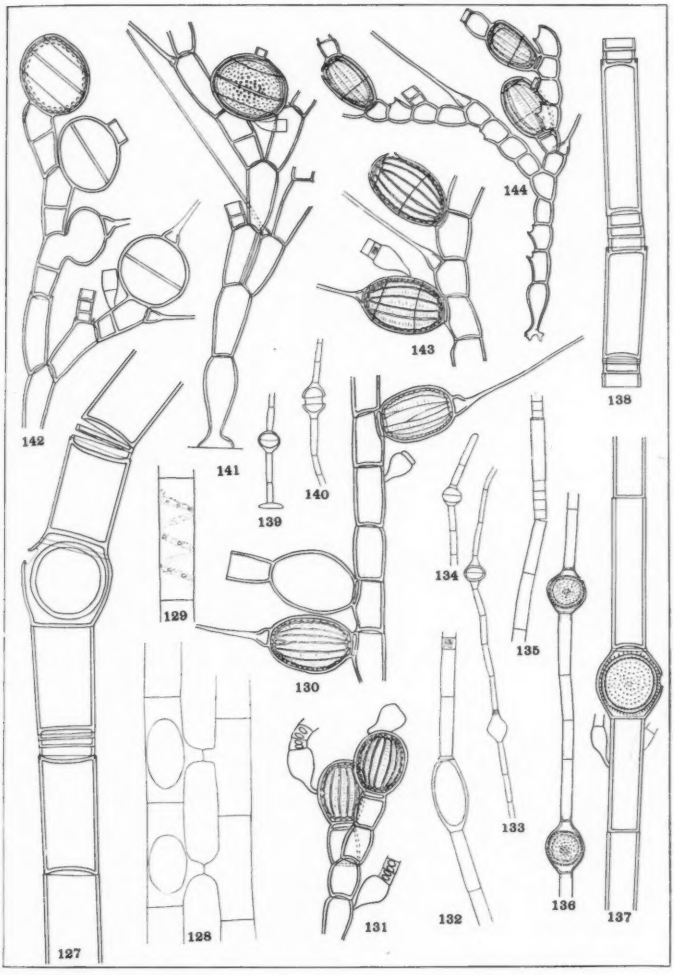

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The Plants of Mount Rainier National Park, Washington

Harold St. John and Fred A. Warren

Location

Mount Rainier National Park is situated in southeastern Pierce County, Washington and in adjacent Lewis County. Its area is 378 square miles. The eastern boundary of the park is the main divide of the Cascade Mountains. Just to the west of this, rises the towering cone of Rainier, reaching an elevation of 14,408 feet.

Topography

The peak forms a nearly symmetrical cone, but its lower slopes are deeply dissected by narrow, entrenched river valleys. Between these are precipitous ridges, the most prominent being: Tatoosh Range on the south; Mount Wow on the southwest; Alki Crest and Mother Mountain on the northwest; Sluskin Mountains on the north; Sourdough Mountain on the northeast; and Governor's Ridge and Cowlitz Chimneys on the east.

Climate

The park lies in a region of humid forests. Full records of the climate of its many diverse areas are not available, but the following figures will give some idea of the amount of precipitation. During the winter of 1932-1933 the snowfall totaled as follows: Longmire, 222 inches; Paradise Valley, 797 inches; Yakima Park, 479 inches; Mowich Lake, 402 inches; and Carbon River Entrance, 65 inches.

Geology

The country rock of the Cascade divide and of the lower ridges is igneous. The cone of Mount Rainier is volcanic, largely of a porphyritic andesite, but also of basalt flows and pummice fields. The volcano is still somewhat active, as slight eruptions were recorded in 1843, 1854, 1858, and 1870. At the summit are fumeroles issuing hot steam through the snow, and near the base are hot mineral springs. Hence, the volcano must be considered active or potentially so.

Snow and ice cover and adorn the mountain. Its upper slopes have 45 square miles permanently white with this frozen covering. In the crater and on the uppermost slopes are the snow fields. These feed the great glaciers that push down the deep valleys far below tree line. In 1903 Prof. J. N. Leconte measured the forward movement of the glaciers, and found that the Nisqually Glacier advanced on the average 16 inches a day. As on other glacier-capped regions, the glaciers have been diminishing in size, due to a lessening precipitation or a warming climate. Between 1857 and 1928 the foot of the Nisqually Glacier has receded a distance nearly of 3000 feet.

Vegetation

Four zones of vegetation or life zones are here recognized. A brief description of each zone is given, with a short list of the characteristic plants. It should be kept in mind that these indicator species are not necessarily confined to the single zone, but that they reach their maximum growth or abundance within it.

Humid Transition Zone. It reaches from the park boundaries at 1,500 or 1,800 feet up to about 3,500 feet altitude. The natural growth is a dense, deep forest with many towering, magnificent trees. Most abundant is the Douglas Fir *(Pseudotsuga mucronata).* A specimen of this near the Kautz Creek bridge, called the Columbus Tree, is 8 feet in diameter and is estimated to be 700 years old. In the moister valleys the Giant Cedar *(Thuja plicata)* is common. It is notable for its thin shreddy bark and its reddish, straight, fragrant wood that so well resists moisture and decay. The Western Hemlock *(Tsuga heterophylla)* is also common. Conspicuous flowering plants are: Wake Robin *(Trillium ovatum);* Wood Anemone *(Anemone deltoidea);* Canadian Dogwood *(Cornus canadensis);* Indian Pipe *(Monotropa uniflora);* Pipsisewa *(Chimaphila umbellata,* var. *occidentalis);* Queen Cup *(Clintonia uniflora);* Salmon-berry *(Rubus spectabilis);* Skunk Cabbage *(Lysichitum americanum);* Twin-flower *(Linnaea borealis,* var. *longiflora);* and Red Huckleberry *(Vaccinium parvifolium).* Common ferns are the Sword Fern *(Polystichum munitum);* and the Deer Fern *(Struthiopteris Spicant).*

Canadian Zone. It is found between 3,500 and 5,000 feet elevation. Here a dense forest of moderate sized or small trees covers the slopes. Conspicuous ones are the Noble Fir *(Abies nobilis);* White Pine *(Pinus monticola);* and the Alaska Cedar *(Chamaecyparis nootkatensis).* Other representative plants are: Stonecrop (*Sedum* spp.); Pentstemon *(Pentstemon nemorosus* and *P. ovatus);* Ragwort *(Senecio triangularis);* Luina *(Luina hypoleuca);* and the Black Alder *(Alnus sinuata).* Near the 4,500 foot level, the grassy meadows begin. In these are found Cotton Grass *(Eriophorum angustifolium);* Rosy Spiraea *(Spiraea densiflora);* Monkey Flower *(Mimulus Lewisii);* Speedwells *(Veronica);* Willows *(Salix);* and Sedges *(Carex).*

Hudsonian Zone. This is found at from 5,000 to 6,500 feet elevation. Here on knolls and ridges where the snow does not drift so deep or last so long, are picturesque clumps of evergreen trees. Some are battered and twisted, and even almost prostrate, but the central ones raise a short, stout trunk, with a dense, irregular, wind-beaten crown. Conspicuous among these trees are the Alpine Fir *(Abies lasiocarpa);* White Barked Pine *(Pinus albicaulis);* and the Black Hemlock *(Tsuga Mertensiana).* The valleys and slopes are piled deep with snow for about nine months. When the snow begins to melt a few of the hardiest flowers will even protrude their buds through the snow. During the warm days of July the snow vanishes and the turfy slopes or meadows burst into bloom. These are the mountain meadows, the glory of the park. The first flowers make them white, as if the snow had returned. These give way to red flowers, and near the end of the summer the blue and purple flowers predominate. The mountain flowers are larger

and sweeter than those of the lowlands. Here in the mountain meadows the whole blossoming of the year is concentrated into a short span of about two months. It is the greatest flower show of the park. Abundant and beautiful flowers are the Avalanch Lily *(Erythronium montanum)*; the Mountain Dock *(Polygonum bistortoides)*; Western Anemone *(Anemone occidentalis)*; White Heather *(Cassiope Mertensiana)*; Paint Brush *(Castilleja oreopola,* and *C. rupicola)*; Red Heather *(Phyllodoce empetriformis)*; Valerian *(Valeriana sitchensis)*; Alpine Monkey Flower *(Mimulus Tilingii)*; Cinquefoil *(Potentilla flabellifolia)*; Gentian *(Gentiana calycosa)*; and Lupine *(Lupinus subalpinus* vars.).

Arctic-Alpine Zone.- It occurs from 6,500 to 10,000 feet. Above tree line and above the meadows are still found some plants. On steep pummice slopes or in crevices of the volcanic rocks are a few species of small or dwarfed perennials. These sturdy, cold-resistant plants are: Lyall's Lupine *(Lupinus Lyallii)* Yellow Heather *(Phyllodoce glandulifera)*; Jacob's Ladder *(Polemonium elegans)*; Phlox *(Phlox cespitosa)*; Golden Draba *(Draba aureola)*; Mountain Candytuft *(Smelowskia ovalis)* Golden Aster *(Haplopappus Brandegei)*; and Mountain Bluegrass *(Poa Lettermani)*. Flowering plants, *(Smelowskia)*, have been found on the Beehive at 11,000 feet. At the very summit of the mountain, mosses have been found on the rocks.

Plants First Discovered on Mount Rainier

The following species were described from specimens collected on Mount Rainier:

	(Eriogonum compositum, var. *pilicaulis).*
Mountain Bitter-root	*(Lewisia exarticulata).*
Chickweed	*(Stellaria washingtoniana).*
	(Draba lonchocarpa, var. *semilonsa).*
Cinquefoil	*(Potentilla flabellifolia).*
Lupine	*(Lupinus volcanicus).*
Locoweed	*(Oxytropis Mazama).*
Mountain Parsley	*(Hesperogenia Stricklandii).*
Lovage	*(Ligusticum purpureum).*
Mountain Blueberry	*(Vaccinium deliciosum).*
Gentian	*(Gentiana calycosa).*
Jacobs Ladder	*(Polemonium elegans).*
Waterleaf	*(Hydrophyllum congestum).*
Paint Brush	*(Castilleja rupicola).*
Common Lousewort	*(Pedicularis contorta).*
Duckbill Lousewort	*(Pedicularis ornithorhynca).*
Rainier Lousewort	*(Pedicularis rainierensis).*
Pentstemon	*(Pentstemon rupicola).*
Allen's Speedwell	*(Veronica Cusickii,* var. *Allenii).*
Arnica	*(Arnica aspera).*
Aster	*(Aster pulchellus).*
Flett's Hawkweed	*(Hieracium Flettii).*
Sweet Colt's Foot	*(Petasites nivalis).*
Rainieria	*(Rainieria stricta).*

Botanical Collectors

Dr. William Fraser Tolmie was a physician at the Hudson's Bay Company post, Nisqually House, a site not far from the present Nisqually,

Washington. In August and September 1833 he was given ten days leave to collect medicinal plants in the mountains. His party reached the present boundary of the park, climbed the mountain slope, and attained the meadows of the Hudsonian Zone. His collections were made on September 2nd and 3rd, 1833, and contained several new species, including: Duckbill Lousewort *(Pedicularis ornithorhynca);* Beard Tongue *(Pentstemon Tolmiei);* Gentian *(Gentiana calycosa);* Cinquefoil *(Potentilla flabellifolia);* Wood Rush *(Luzula arcuata);* Aster *(Aster pulchellus);* and Tolmie's Saxifrage *(Saxifraga Tolmiei).*

Rev. E. C. Smith in 1888 and 1889, made collections from the south slopes. Dr. E. L. Greene collected on the north slopes in 1889, and described several new species. Prof. C. V. Piper made extensive collections in 1888, 1889 and 1895. He named several new plants from the Park. Perhaps one of the most extensive collections made was by Prof. O. D. Allen, in 1895 and later years. His plants were collected mainly from the south and southwest portions of the Park. The greatest conribution to the knowledge of the plants of Mount Rainier was made by J. B. Flett. His collections from various parts of the region, were made between 1895 and 1920.

There have been a number of people who have made smaller collections, these include: M. W. Gorman, 1897; Dr. M. W. Lyon, jr., 1905; Dr. Adolph Engler, 1913; Winona Bailey, 1912 and other years; Prof. W. T. Shaw, 1919; Dr. H. St. John, 1923; J. M. Grant, 1925; G. N. Jones, 1925 and 1926; Dr. F. L. Pickett, 1926; A. A. Heller, 1928; R. A. Dilwert, 1931; J. W. Thompson, 1930 and 1931; Dr. F. W. Pennell, 1931; Dr. E. T. Wherry, 1931, and Dr. Le Roy Abrams.

Mr. Warren while in the employ of the National Park Service during the seasons of 1926, 1927, 1928, 1930, 1931, 1932, and 1933 made extensive collections. These were mostly from the following districts: Carbon River, Nisqually, Paradise, and White River districts. Smaller collections were also made from Ohanapecosh, Stevens Canyon, and Tipsoo Lake regions.

Publications

The first publication treating the plan life of Rainier National Park was "The Flora of Mount Rainier," by Prof. C. V. Piper, published in Mazama 2: 93-117, 1901. In this Prof. Piper listed 295 species. He later published another article "Additions and Corrections, to the List of Mount Rainier Plants," in Mazama 2: no. 4, December 1904. In this article were 12 additional records.

The next publication was also by Prof. C. V. Piper, "Flora of the State of Washington," Contributions from the United States National Herbarium, 11: 1-637, 1906. In this great work, Mr. Piper cited many specimens from Mount Rainier.

In the book "The Mountain That Was God," by J. H. Williams, published in 1911, Mr. J. B. Flett contributed the chapter "The Flora of Mountain Slopes." In this interesting article, written in popular style, Mr. Flett, says, "The writer has a list of about three hundred and sixty species from the Mountain."

A book containing much general information, "Mount Rainier, A Record of Exploration" by E. S. Meany, 1916, contains a chapter "The Flora of Mount Rainier," written by C. V. Piper. He says, "The list of plants given here number 315 species."

The profusely illustrated booklet, "Features of the Flora of Mount Rainier National Park," by Mr. J. B. Flett, printed by the National Park Service in 1922, gives a total of 532 plants.

Mr. F. W. Schmoe in his elaborately illustrated book, "Our Greatest Mountain" published in 1925, in Chapter VI "Life Zones on Mount Rainier" gives a total of 557 plants.

The list here prepared totals 695 plants. The writers believe that by thorough study of certain areas, the number of known plants will be considerably increased. These regions are: between Mystic Lake and Yakima Park, then around to the Cowlitz River; and the area along the Cascade Divide.

Suitable common names have been used when they could be found, but many plants do not have them. Sources that have been used in search of these are Piper and Beattie's, "Flora of the Northwest Coast"; Fry and Rigg's "Northwest Flora"; Abrams' "Flora of the Pacific States"; Schmoe's "Our Greatest Mountain," and Piper's "Flora of the State of Washington."

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The writers greatly appreciate help in the identification of several plant groups, by the following persons: Dr. S. F. Blake, Bureau of Plant Industry, Washington, D.C., on various *Compositae* and the genus *Juncus;* Dr. F. W. Pennell, Academy of Natural Sciences, Philadelphia, the *Scrophulariaceae;* Dr. E. T. Wherry, University of Pennsylvania, the *Polemoniaceae;* Dr. C. P. Smith of San Jose, California, the genus *Lupinus;* Dr. Rimo Bacigalupi, Stanford University, California, for suggestions on *Saxifraga;* Miss Agnes Chase, Smithsonian Institution, Washington, D.C., the *Gramineae;* Dr. G. N. Jones, University of Washington, Seattle, Washington, for helping with miscellaneous groups; Dr. George T. Moore, Missouri Botanical Gardens, St. Louis, Mo.; and Mr. C. A. Weatherby, Gray Herbarium, Harvard University, Cambridge, Mass., for looking up certain plants of the O. D. Allen collection, to which the writers did not have access.

The following have kindly given us free access to their collections: Mr. R. A. Diettert, University of Idaho, Moscow, Idaho; Mr. J. W. Thompson, Seattle, Washington; Mr. M. C. Riley, Spokane, Washington; Mr. Paul Eide and Mr. George Newton of Puyallup, Washington; and the late J. M. Grant of Marysville, Washington.

Specimens collected by the following botanists are a part of the Herbarium of the State College of Washington and were freely consulted: Rev. E. C. Smith; Prof. C. V. Piper; Prof. O. D. Allen; Mr. J. B. Flett; Dr. G. N. Jones; Dr. F. L. Pickett; Miss Winona Bailey; Dr. H. St. John; and F. A. Warren.

EXPLANATIONS

In the following catalogue of the flora, the plants are listed alphabetically by scientific names under each family. For the commoner species are given the habitat, the local distribution, and the abundance. For the rare plants or

for those newly recorded, are given definite localities, with the collector's name and number. Adventive plants are indicated by an asterisk.

Catalogue of the Flowering Plants

Pinaceae

Abies amabilis (Dougl.) Forbes, Lovely Fir. Forests, 2,000 to 3,500 feet very common.

Abies grandis Lindl., White Fir. Forests, 2,000 to 3,500 feet, quite common.

Abies lasiocarpa (Hook.) Nutt., Alpine Fir. Open slopes, 2,700 to 6,500 feet, common.

Abies nobilis Lindl., Noble Fir. Forests, 2,200 to 6,500 feet, quite common.

Chamaecyparis nootkatensis (Lamb.) Spach., Alaska Cedar. Open woods, 3,000 to 7,000 feet, very common. A tree of this species on the trail from Ipsut Creek to Mowich Lake measures seven feet ten inches in diameter.

Juniperus communis L., var. *montana* Ait., Mountain Juniper. Dry rocky places, 2,700 to 7,000 feet, quite common.

Picea albertiana S. Brown, Alberta Spruce. Exposed rocky places, 5,000 to 6,500 feet, common especially on the north side.

Picea columbiana Lemmon, Columbia Spruce. Rocky river bottoms, Ipsut Creek, rare.

Pinus albicaulis Engelm., White Barked Pine. Dry and rocky ridges, 6,000 to 8,000 feet, common in Yakima Park.

Pinus contorta Dougl., var. *latifolia* Engelm., Lodgepole Pine. Rocky soil, 2,700 to 7,000 feet, fairly common in the White River area.

Pinus monticola Dougl., Western White Pine. Forests, 2,000 to 6,000 feet, fairly common.

Pseudotsuga mucronata (Raf.) Sudw., Douglas Fir. Forests, 2,000 to 5,000 feet, very common.

Thuja plicata Donn, Giant Cedar. Moist forests, 2,000 to 5,000 feet, very common.

Tsuga heterophylla (Raf.) Sarg., Western Hemlock. Forests, 2,000 to 6,000 feet, very abundant.

Tsuga Mertensiana (Bong.) Carr., Mountain Hemlock. Open slopes, 4,000 to 7,000 feet, quite common.

Typhaceae

Typha latifolia L., Cat-tail. Low wet places, Longmire, Warren 1739.

Sparganiaceae

Sparganium angustifolium Michx., Narrow-leaved Bur-reed. Shallow water, small ponds, not common.

Sparganium minimum Fries, Small Bur-reed. Shallow water, ponds, fairly common.

Potamogetonaceae

Potamogeton natans L., Pondweed. Shallow water, small pond, upper Tahoma Creek, Warren 1591, rare.

Gramineae

Agropyron trachycaulum (Link) Malte, var. *majus* (Vasey) Fern., Bearded Wheat Grass. Mount Wow, J. B. Flett, September 20, 1919.

Agropyron Smithii Rydb., Western Wheat Grass. Sandy soil, near Lake Allen trail, Warren 1703.

**Agrostris stolonifera* L., var. *major* (Gaud.) Farw., Redtop. Waste places, Longmire, Warren 1690.

Agrostis aequivalvis Trin., Northern Bent Grass. "Common on the banks of Paradise River up to 5,000 feet" Piper, Mazama II, no. 2.

Agrostis exarata Trin., Western Bent Grass. Moist or dry open ground, fairly common.

Agrostis geminata Trin., Alpine Hair Grass, Burrough's Mountain, 7,800 feet, Flett, August 1919.

Agrostis humilis Vasey, Mountain Bent Grass. Moist places, 6,000 to 9,000 feet, common.

Agrostis oregonensis Vasey, Oregon Bent Grass. Wet places, rare.

Agrostis pallens Trin., var. *Vaseyi* St. John, Leafy Bent Grass. Sandy soil, Canyon Bridge, Warren 1771.

Agrostis Rossae Vasey, Ross's Bent Grass. Moist slopes, 5,000 to 6,500 feet, very common.

Agrostis scabra Willd., Hair Grass. Moist places up to 5,000 feet, fairly common.

Agrostris Thurberiana Hitchc., Thurber's Bent Grass. Moist places. Fairly common.

**Avena fatua* L., Wild Oats. Waste places, Longmire, Warren 1750.

**Bromus commutatus* Schrad., Downy Cheat. Waste places, Longmire, Warren 1644, 1686.

Bromus marginatus Nees, Mountain Brome Grass. Open hillsides, rare.

**Bromus tectorum* L., Downy Brome Grass. Waste places, Longmire, Warren 1647.

Bromus vulgaris (Hook.) Shear, Narrow-flowered Brome Grass. Woods, rare.

Calamagrostis canadensis (Michx.) Nutt., Blue Joint Grass. Moist places, 4,000 to 6,000 feet, quite common.

Calamagrostis purpurascens R. Br., Purple Reed Grass. Rocky places, 2,000 to 7,000 feet, fairly common.

Cinna latifolia (Trev.) Griseb., Slender Wood Grass. Moist places, 2,700 to 5,500 feet, fairly common.

**Cynosurus cristatus* L., Crested Dog's Tail. Waste places, Longmire, Warren 1577.

**Dactylis glomerata* L., Orchard Grass. Waste places, Longmire, Warren 1645.

Danthonia intermedia Vasey, Mountain Oat Grass. Rocky places, not common.

Deschampsia atropurpurea (Wahl.) Scheele, Mountain Hair Grass. Dry slopes, abundant.

Deschampsia cespitosa Beauv., Tufted Hair Grass. Moist soils, 4,000 to 6,000 feet, common.

Deschampsia danthonioides (Trin.) Munro, Annual Hair Grass. Sandy soil, Canyon Bridge, Warren 1764.

Deschampsia elongata (Hook.) Munro, Slender Hair Grass. Open ground, very abundant.

Elymus glaucus Buckl., Western Rye Grass. Rocky soil, 3,000 to 6,000 feet, common.

Elymus virescens Piper, Pacific Rye Grass. Moist soil, uncommon.

Festuca brachyphylla Schultes, Small Sheep Fescue. Open slopes, 6,000 to 9,000 feet, common.

Festuca elatior L., Meadow Fescue. Gravelly soil, Longmire, Warren 1584, and 1751.

Festuca microstachys Nutt., Nuttall's Fescue. Dry sandy soil, Stevens Creek, Warren 578, rare.

Festuca occidentalis Hook., Western Fescue. Dry ridges, quite common.

Festuca rubra L., Red Fescue. Sandy soil, Steven's Creek Crossing, Warren 1760.

Festuca subulata Trin., Nodding Fescue. Moist places, 2,000 to 4,000 feet, common.

Festuca viridula Vasey, Mountain Bunch Grass. Moist places, 4,800 to 7,000 feet, abundant.

Glyceria borealis (Nash) Batchelder, Northern Manna Grass. Wet places, rather rare.

Glyceria pauciflora Presl, Manna Grass. Wet meadows, fairly common.

**Hordeum jubatum* L., Squirrel Tail Grass. Waste places, Longmire, Warren 1619.

**Lolium multiflorum* Lam., Italian Rye Grass. Waste places, Longmire, Warren 1689.

Melica subulata (Griseb.) Scribn., Alaska Onion Grass. Moist places, rather rare.

Muhlenbergia filiformis (Thurb.) Rydb., Slender Muhlenbergia. Sandy soil, Canyon Bridge, Warren 1767.

Phleum alpinum L., Mountain Timothy. Alpine meadows, 5,000 to 6,500 feet, abundant.

**Phleum pratense* L., Timothy. Waste places, Longmire, observed August 15, 1932.

Pleuropogon refractus (Gray) Benth., Nodding Pleuropogon. Swampy places, very common.

**Poa annua* L., Annual Blue Grass. Waste places, Longmire, Warren 1646.

Poa arctica R. Br., Arctic Blue Grass. Alpine meadows, 5,000 to 10,000 feet, abundant.

Poa epilis Scribn., Mountain Blue Grass. Dry slopes, 5,000 to 7,000 feet, common.

Poa gracillima Vasey, Pacific Blue Grass. Rocky places, 2,000 to 7,000 feet, abundant.

Poa Lettermani Vasey, Letterman's Blue Grass. Rocky places, 8,500 to 10,000 feet, fairly common.

Poa macroclada Rydb., Blue Grass. Rocky soil, Canyon Bridge, Warren 1763.

Poa nervosa (Hook.) Vasey, Hooker's Blue Grass. Moist places, rather rare.

**Poa pratensis* L., Kentucky Blue Grass. Open woods, common in some localities.

Poa Pringlei Scribn., Pringle's Blue Grass. Rocky places, 7,500 to 10,000 feet, rather rare.

Poa scabrella (Thurb.) Benth., Blue Grass. Dry soil, Allen 182, rare.

**Polypogon monspeliensis* (L.) Desf., Rabbit's Foot Grass. Swamp, Longmire, Warren 580.

**Puccinellia distans* (L.) Parl., European Alkali Grass. Wet soil, Longmire, Warren 1651.

Setaria viridis (L.) Beauv., Green Fox Tail. Waste places, Longmire, Warren 1691.

Sitanion Hanseni (Scribn.) J. G. Smith, Hansen's Squirrel-tail. Dry rocky soil, rare.

Sitanion elymoides Raf., Bottle-brush Squirrel-tail. Dry rocky soil, 4,000 to 8,000 feet, common.

Stipa occidentalis Thurb., Western Stipa. Open dry woods, 4,500 to 6,000 feet, rather rare.

Trisetum canescens Buckl., Tall Oat Grass. Open slopes, rare.

Trisetum cernuum Trin., Nodding Trisetum. Moist places, 2,100 to 5,500 feet, common.

Trisetum spicatum (L.) Richter, var. *Michauxii* St. John, Downy Oat Grass. Open slopes, common.

Cyperaceae

Carex ablata Bailey, Sedge. Wet places, 4,000 to 6,000 feet, common.

Carex accedens Holm, Mount Rainier Sedge. Alpine meadows, rare.

Carex amplifolia Boott, Ample-leaved Sedge. Wet soil, rare.

Carex angustior Mackenzie, Narrow Sedge. Wet places, rare.

Carex arcta Boott, Clustered Sedge. Moist soils, rare.

Carex Bolanderi Olney, Bolander's Sedge. Woods, rare.

Carex brunnescens (Pers.) Poir., Brown Sedge. Wet places, 5,000 to 7,000 feet, fairly common.

Carex canescens L., Silvery Sedge. Swamps abundant.

Carex Cusickii Mackenzie, Cusick's Sedge. Wet meadows, fairly common.

Carex Engelmanii Bailey, Engelmann Sedge. Moist places, 7,000 to 9,500 feet.

Carex exsiccata Bailey, Western Inflated Sedge. Wet places, 2,000 to 3,500 feet, fairly common.

Carex Geyeri Boott, Geyer's Sedge. Dry slopes, rather rare.

Carex gymnoclada Holm, Alpine Sedge. Wet meadows, 4,000 to 6,000 feet, abundant.

Carex Hepburnii Boott, Hepburn's Sedge. Dry slopes, 6,000 to 10,000 feet, common.

Carex illota Bailey, Sedge. Alpine meadows, rare.
Carex Kelloggii W. Boott, Kellogg's Sedge. Moist meadows, 2,700 to 5,500 feet, common.
Carex laeviculmis Meinsh., Smooth Stemmed Sedge. Wet places, 2,500 to 6,000 feet, common.
Carex leptalea Wahlenb., Sedge. Swamp, Longmire, Warren 1632, common.
Carex limosa L., Shore Sedge. Bogs, rare.
Carex Mertensii Prescott, Mertens' Sedge. Moist places, 3,500 to 5,500 feet, abundant.
Carex neurophora Mackenzie, Alpine Nerved Sedge. Wet places, rare.
Carex nigricans C. A. Meyer, Black Sedge. Alpine meadows, 4,500 to 7,000 feet, abundant.
Carex oregonensis Olney, Oregon Sedge. Swamp, Longmire, Warren 1633, not common.
Carex pachystachya Cham., Sedge. Dry ridges, 4,000 to 7,000 feet, common.
Carex phaeocephala Piper, Hare Sedge. Rocky places, 4,800 to 9,000 feet, quite common.
Carex podocarpa R. Br., Tolmie's Sedge. Alpine meadows, 5,000 to 7,000 feet, fairly common.
Carex praegracilis W. Boott., Sedge. Swamp, Longmire, Warren 1631, fairly common.
Carex Preslii Steud., Presl's Sedge. Dry rocky places, 2,700 to 7,500 feet, common.
Carex pyrenaica Wahl., Pyrenaen Sedge. Rocky places, 5,000 to 9,000 feet, common.
Carex Rossii Boott, Ross' Sedge. Moist slopes, 3,500 to 6,500 feet, common.
Carex rostrata Stokes, Beaked Sedge. Swampy places, 2,700 to 4,000 feet, fairly common.
Carex spectabilis Dew., Showy Sedge. Moist places, 4,000 to 9,000 feet, abundant.
Eriophorum angustifolium Roth., Cotton Grass. Wet places, 4,000 to 6,000 feet, abundant.
Eriophorum Chamissonis C. A. Meyer, Cotton Grass. Wet places, rare.
Scirpus cespitosus L., var. *callosus* Bigel., Tufted Club Rush. Mountain Meadows, J. B. Flett, September 1, 1919.
Scirpus microcarpus Presl, Small Fruited Rush. Wet places, 2,700 to 4,500 feet, not common.

Araceae

Lysichitum americanum Hultén & St. John, Skunk Cabbage. Wet places, 2,000 to 3,500 feet, very common.

Juncaceae

Juncus balticus Willd., Baltic Rush. Moist places, rare.
Juncus bufonius L., Common Toad Rush. Moist places, Longmire, Warren 1637 and 1700.
Juncus Covillei Piper, Coville's Rush. Wet places, Longmire, Piper, August 1895; Warren 1650.

Juncus Drummondii E. Mey., Drummond's Rush. Wet places, 4,000 to 7,500 feet, common.

Juncus filiformis L., Slender Rush. Moist places, rare.

Juncus Mertensianus Bong., Mertens' Rush. Alpine meadows, 4,500 to 6,500 feet, abundant.

Juncus Parryi Engelm., Parry's Rush. Rocky places, 4,000 to 8,000 feet, common.

Juncus Regelii Buch., Regel's Rush. Wet places, rather scarce.

Juncus xiphoides E. Mey., var. *triandrus* Engelm. Rush. Wet places, 2,500 to 5,500 feet, fairly common.

Luzula arcuata Wahl., var. *unalaschkensis* Buch., Alpine Wood Rush. Collected by J. B. Flett. In a letter from C. V. Piper to Mr. Flett dated at Washington, D.C., June 1, 1920, "One of your other plants was exceedingly interesting, namely, one of the species of Luzula, which turns up to be *Luzula arcuata* var. *unalaschkensis*. This was originally described from Unalaska, but has been reported from the mountains of British Columbia, but this is the first time it has been found within the United States territory." Mr. G. N. Jones of the University of Washington has given further information, he says, "According to Flett (July, 1932) he collected the specimens on Mazama Ridge, near Sluskin Falls, Paradise Valley."

Though most of Mr. Flett's collection made in 1919, is in the Herbarium at Pullman, this material seems to be missing. This is apparently the first record for the United States as well as the State of Washington.

Luzula campestris (L.) DC., var. *comosa* (Mey.) Fern., Wood Rush. Open woods, 2,700 to 5,500 feet, quite common.

Luzula glabrata (Hoppe) Desv., Smooth Wood Rush. Rocky places, rare.

Luzula parviflora (Ehrh.) Desv., Small Flowered Wood Rush. Moist places, 2,500 to 6,500 feet, common.

Luzula Piperi (Coville) Henry, Piper's Wood Rush. Rocky places, 4,000 to 7,000 feet, common.

Luzula spicata (L.) DC., Spiked Wood Rush. Rocky places, 6,000 to 9,000 feet, abundant.

Liliaceae

Allium cernuum Roth., Nodding Onion. Upper rocky slopes, Mount Wow.

Allium validum Wats., Meadow Onion. Wet meadows, Mountain Meadows, Flett 275, 3183; Warren 808.

Clintonia uniflora (Schult.) Kunth, Queen Cup. Moist woods, 2,000 to 5,000 feet, very abundant.

Disporum oreganum (Wats.) W. Miller, Oregon Fairy Bells. Dry soil, Upper Nisqually Valley, Allen 148.

Erythronium grandiflorum Pursh, var. *pallidum* St. John, Glacier Lily. Alpine meadows, 4,500 to 6,000 feet, fairly common.

Erythronium montanum Wats., Avalanche Lily. Alpine meadows, 4,000 to 6,000 feet, abundant.

Fritillaria lanceolata Pursh, Mission Bells. Mount Wow, Allen 235, rare.

Lilium columbianum Hanson, Tiger Lily. Open slopes 2,500 to 6,000 feet, quite common.

Lloydia serotina (L.) Sweet, Mountain Lily. Rocky ledges, 6,000 to 7,000 feet, Mount Wow, Warren 782; Crystal Mt., Warren 566.

Maianthemum dilatatum (Wood) Nelson and Macbride, Wild Lily-of-the-Valley. Moist woods, common.

Smilacina racemosa (L.) Desf., False Solomon's Seal. Moist woods, 2,000 to 5,500 feet, quite common.

Smilacina stellata (L.) Desf., Solomon's Seal. Moist woods, 2,000 to 3,000 feet, not common.

Stenanthium occidentale Gray, Bronze Bells. Moist places, 2,000 to 6,000 feet, common.

Streptopus amplexifolius (L.) DC., Twisted Stalk. Moist woods, quite common.

Streptopus curvipes Vail, Rose Flowered Twisted Stalk. Moist woods, 2,000 to 4,500 feet, fairly common.

Streptopus streptopoides (Ledeb.) Nelson & Macbride, Small Twisted Stalk. Mossy woods, Klapatche Ridge, Warren 607; also observed on trail between Ipsut Creek and Ipsut Pass.

Tofieldia occidentalis Wats., Western Asphodel. Wet places, 2,700 to 6,000 feet, quite common.

Trillium ovatum Pursh, Trillium or Wake Robin. Moist woods, 2,000 to 5,000 feet, very abundant.

Veratrum caudatum Heller, White False Hellebore. Wet meadows, Longmire, Warren 1600.

Veratrum Eschscholtzii Gray, Green False Hellebore. Grassy slopes, 4,000 to 6,000 feet, abundant.

Xerophyllum tenax (Pursh) Nutt., Bear Grass. Open slopes, 2,500 to 6,000 feet, very abundant.

Iridaceae

Sisyrinchium idahoense Bickn., Blue-eyed Grass. Wet ground, Longmire, Flett 3317; Warren 623.

Orchidaceae

Calypso bulbosa (L.) Oakes, f. *occidentalis* Holz., Lady Slipper. Moist woods, fairly common.

Cephalanthera Austinae (Gray) Heller, Phantom Orchid. Coniferous woods, upper Nisqually valley, Allen 149.

Corallorhiza maculata Raf., Coral Root. Deep woods, rather rare.

Corallorhiza Mertensiana Bong., Mertens' Coral Root. Moist woods, 2,000 to 5,000 feet, very common.

Goodyera decipiens (Hook.) F. T. Hubbard, Rattle-snake Plantain. Mossy woods, 2,000 to 5,000 feet, very common.

Habenaria dilatata (Pursh) Hook., var. *leucostachys* (Lindl.) Ames, White Bog Orchid. Wet meadows, 2,000 to 4,500 feet, quite common.

Habenaria saccata Greene, Green Bog Orchid. Wet places, 2,500 to 6,000 feet, common.

Habenaria unalascensis (Spreng.) Wats., Alaska Bog Orchid. Rocky soil, Ohanapecosh River, Flett 3195; North Puyallup River, Warren 1534.

Listera caurina Piper, Northwestern Twayblade. Moist woods, 2,000 to 4,000 feet, quite common.

Listera convallarioides (Sw.) Nutt., Broad-lipped Twayblade. Mossy woods, fairly common.

Listera cordata (L.) R. Br., Heart-leaved Twayblade. Moist woods, 2,500 to 4,000 feet, common.

Spiranthes Romanzoffiana Cham., Hooded Ladies Tresses. Wet places, 2,700 to 6,000 feet, common.

Salicaceae

Populus trichocarpa T. & G., Black Cotton-wood. Along the rivers at low elevation.

Salix Barclayi Anderss., Barclay's Willow. Wet places, 4,000 to 5,500 feet, common.

Salix cascadensis Cockerell, Cascade Willow. Pumice soil, Flett 2118.

Salix commutata Bebb., Willow. Wet places, 4,000 to 5,500 feet, common.

Salix Geyeriana Anderss., var. *meleina* Henry, Geyer's Willow. Open wet places, rather rare.

Salix lasiandra Benth., Red Willow. Stream banks, 2,000 to 4,000 feet, common.

Salix lutea Nutt., Yellow Willow. Wet places, Owyhigh Lakes, W. T. Shaw.

Salix mackenziana (Hook.) Barratt, Mackenzie Willow. Ohanapecosh Hot Springs, July 25, 1919, J. B. Flett.

Salix monticola Bebb., Willow. Wet places, 2,000 to 4,000 feet, rare.

Salix nivalis Hook., Alpine Willow. Rocky places, 6,000 to 8,000 feet, rather rare.

Salix pennata Ball, Feather-vein Willow. Open slopes, 4,000 to 6,000 feet, rare.

Salix Scouleriana Barratt, Scouler's Willow. Rocky places, 2,000 to 5,000 feet, common.

Salix sitchensis Sanson, Sitka Willow. Wet places, 2,700 to 5,000 feet, common.

Betulaceae

Alnus oregona Nutt., Red Alder. Moist woods, fairly common.

Alnus sinuata (Regel) Rydb., Mountain Alder. Rocky slopes, 2,500 to 5,500 feet, very common.

Urticaceae

Urtica Lyallii S. Wats., Nettle. Moist places, lower elevations, very common.

Loranthaceae

Arceuthobium Douglasii Engelm., var. *tsugensis* (Rosendahl) M. E. Jones Hemlock Mistletoe. On Tsuga Mertensiana, Upper Nisqually Valley, Allen 303.

Aristolochiaceae

Asarum caudatum Lindl., Wild Ginger. Moist woods, 2,000 to 4,500 feet, common.

Polygonaceae

Eriogonum compositum Dougl., var. *pilicaulis* St. John & Warren, Woolly Knees. Rocky places, 5,000 to 6,000 feet, fairly common.

Eriogonum ovalifolium Nutt. Rocky soil, Owyhigh, Flett 3056; Cowlitz Rocks, August 3, 1932, Verrol Swartz.

Eriogonum pyrolaefolium Hook., var. *coryphaeum* T. & G. Rocky soil, 5,000 to 9,000 feet, quite common.

Oxyria dignya (L.) Hill, Mountain Sorrel. Dry rocky soil, 5,000 to 6,000 feet, common.

**Polygonum aviculare* L., Smart Weed. Gravelly soil, Longmire, Warren 1618, uncommon.

Polygonum bistortoides Pursh, Mountain Dock. Alpine meadows, 5,000 to 6,000 feet, common.

**Polygonum Convolvulus* L., Wild Buckwheat. Gravelly soil, observed at Longmire, 1932.

Polygonum Douglasii Greene, Douglas' Dock. Dry rocky slopes, 4,000 to 5,000 feet, rare.

Polygonum Kelloggii Greene, Kellogg's Dock. Open slopes, rare, St. John 7941.

**Polygonum lapathifolium* L., Smartweed. Gravelly soil, Longmire, Warren 1746.

Polygonum minimum Wats., Little Dock. Dry rocky slopes, 4,000 to 6,000 feet, common.

Polygonum Newberryi Small, Newberry's Dock. Rocky soil, 6,000 to 8,000 feet, common.

**Rumex Acetosella* L., Sheep Sorrel. Waste places up to 5,500 feet, fairly common.

**Rumex crispus* L., Dock. Gravelly soil, Longmire, Warren 1622, not common.

Rumex mexicanus Meisn., Dock. Wet places, Glacier Basin and Longmire.

Chenopodiaceae

**Chenopodium album* L., Pigweed. Gravelly soil, Longmire, Warren 1752.

Portulacaceae

Claytonia asarifolia Bong., Large-flowered Miners Lettuce. Wet soils, 4,000 to 6,000 feet, fairly common.

Claytonia lanceolata Pursh, Spring Beauty. Grassy slopes, 5,000 to 6,500 feet, fairly common.

Clayonia linearis Dougl., Narrow-leaved Miners Lettuce. Moist open places, Longmire, Flett 3316.

Claytonia parvifolia Moc., Small-leaved Miners Lettuce. Rocky places, 2,000 to 5,000 feet, common.

Claytonia sibirica L., Siberian Miners Lettuce. Moist places, fairly common.

Lewisia columbiana (Howell) Robinson, Columbian Bitter Root. Rocky places, rare.

Lewisia exarticulata St. John, Little Bitter Root. Steep hillsides, rare, Paradise Valley, Flett 284; Panorama Point, Warren 751.

Lewisia triphylla (Wats.) Robinson, Three-leaved Bitter Root. Rocky places, 5,000 to 6,000 feet, fairly common.

Spraguea multiceps Howell, Pussy-paws. Rocky places, 5,500 to 9,000 feet, abundant.

Caryophyllaceae

Arenaria formosa Fisch., Sandwort. Dry rocky places, 5,000 to 7,000 feet, common.

Arenaria laricifolia L., Sandwort. Rocky places, 5,000 to 6,000 feee, common.

Arenaria macrophylla Hook., Large-leaved Sandwort. Open woods, 4,000 to 6,500 feet, common.

Arenaria Nuttallii Pax, Nuttall's Sandwort. Pumice soils, rare, Piper August 1895.

Arenaria sajanensis Willd., Sandwort. Rocky places, 6,000 to 8,000 feet, fairly common.

**Arenaria serpyllifolia* L., Sandwort. Moist places, Longmire, Warren 645.

Arenaria verna L., var. *pubescens* (C. & S.) Fernald. Rocky soils, 4,000 to 6,000 feet, common.

Cerastium arvense L., Chickweed. Dry places, 3,500 to 6,000 feet, common.

**Cerastium vulgatum* L., var., *hirsutum* Fries, Chickweed. Rocky soils, Nisqually Canyon, Warren 415; Longmire, Warren 1693.

**Dianthus barbatus* L., Sweet William. Gravelly soil, near Longmire, Warren 1567, introduced, on mining claims.

Sagina occidentalis Wats., Pearlwort. Rocky places, 4,000 to 6,500 feet, common.

Sagina saginoides (L.) Dalla Torre, var. *hesperia* Fernald, Pearlwort. Rare, Winona Bailey 43; Flett 3063.

Silene acaulis L., var. *exscapa* (All.) DC., Moss Campion. Rocky ledges, 6,000 to 8,000 feet, fairly common.

Silene Cucubalus Wibel, Bladder Campion. Ohanapecosh, Warren 1890, not common.

Silene Douglasii Hook., Douglas' Catchfly. Mount Wow, Allen 124a, rare.

Silene Macounii Wats., Macoun's Catchfly. Rocky soil, 6,000 to 7,000 feet, abundant.

Silene Menziesii Hook., Menzies' Catchfly. Gravelly soil, Longmire, Warren 1711.

**Silene noctiflora* L., Common Catchfly. Gravelly soil, Longmire, Warren 1658.

**Spergula arvensis* L., var. *sativa* (Boenn.) M. & K., Sticky Spurrey. Sandy soil, Longmire, Warren 1695.

**Spergularia rubra* (L.) Presl, Spurrey. Wet places, Longmire, Flett 24.

Stellaria borealis Bigel., Boreal Chickweed. Moist places, 4,000 to 5,500 feet, common.

Stellaria borealis Bigel., var. *Bongardiana* Fernald. Moist woods, Upper Nisqually Valley, Allen 155; Tahoma Creek, Warren 560.

Stellaria borealis Bigel., var. *isophylla* Fernald. Wet places, Longmire, Warren 559.

Stellaria borealis Bigel., var. *simcoei* (Howell) Fernald. Wet places, 3,500 to 6,000 feet, common.

Stellaria crispa Cham. & Schlecht., Chickweed. Wet places, up to 5,000 feet, rather rare.

Stellaria nitens Nutt., Chickweed. Open ground, Upper Nisqually Valley, Allen 154.

Stellaria washingtoniana Robinson, Washington Chickweed. Alder woods, Nisqually Valley, Allen 157.

**Vaccaria vulgaris* Host, Cow-cockle. Gravelly soil, rare, Longmire, Warren 1749.

Nymphaeaceae

Nuphar polysepalum Engelm., Pond Lily. Shallow water, pond near Rick-secker Point, Warren 1737; also observed near Mountain Meadows.

Castalia sp., Water Lily. Observed, Tipsoo Lake, September 12, 1932. It is probable that some person has planted it, as the Water Lily is not native in the state of Washington.

Ranunculaceae

Aconitum columbianum Nutt., Aconite. Moist woods, Ohanapecosh, Flett 3107; Owyhigh, Flett 3102.

Actaea arguta Nutt., Baneberry. Moist woods, up to 4,000 feet, abundant.

Anemone deltoidea Hook., Wood Anemone. Moist woods, Upper Nisqually Valley, Allen 18; Longmire, Warren 474.

Anemone Drummondii Wats., Drummond's Wind Flower. Rocky places, 5,500 to 7,000 feet, common.

Anemone multifida Poir., var. *hudsoniana* DC., Wind Flower. Rocky places, rather rare.

Anemone Lyallii Britt., Lyall's Anemone. Open woods, 2,000 to 5,000 feet, common.

Anemone occidentalis Wats., Western Anemone. Alpine meadows, 5,000 to 6,000 feet, very common.

Aquilegia formosa Fisch., Columbine. Wet places, 2,000 to 5,500 feet, fairly common.

Caltha leptosepala DC., Marsh Marigold. Wet places, 4,500 to 6,500 feet, very abundant.

Delphinium glareosum Greene, Larkspur. Moist slopes, 3,000 to 6,500 feet, quite common.

Delphinium glaucum Wats., Tall Larkspur. Rocky places, 2,500 to 5,000 feet, abundant.

Ranunculus aquatilis L., Water Buttercup. Shallow water, Reflection Lake, Warren 481.

Ranunculus Bongardi Greene, Bongard's Buttercup. Moist places, 2,000 to 4,000 feet, common.

Ranunculus Eschscholtzii Schlecht., Mountain Buttercup. Moist places, 4,500 to 7,000 feet, very abundant.

**Ranunculus repens* L., Buttercup. Rocky soil, 2 miles above Longmire, Warren, 1889, August 4, 1933.

Thalictrum rainierense St. John, Meadow Rue. Meadows, 6,000 feet, Piper 2022.

Trautvetteria grandis Nutt., False Bugbane. Moist woods, 2,500 to 5,500 feet, abundant.

Berberidaceae

Achlys triphylla (Smith) DC., Sweet After Death. Moist woods, fairly common.

Berberis aquifolium Pursh, Oregon Grape. Open woods, rather rare.

Berberis nervosa Pursh, Oregon Grape. Open woods, up to 4,500 feet, fairly common.

Vancouveria hexandra (Hook.) Morr. & Decne. Barrenwort. Woods, lower slopes, common.

Fumariaceae

Corydalis Scouleri Hook., Tall Bleeding Heart. Moist woods, 2,000 to 5,000 feet, abundant.

Dicentra formosa (Andr.) DC., Bleeding Heart. Moist places, 2,000 to 4,500 feet, fairly common.

Dicentra uniflora Kellogg, One-Flowered Bleeding Heart. Chinook Pass, 5,300 feet, English, June 21, 1936.

Cruciferae

Arabis Drummondii Gray, var. *typica* Hopkins, Drummond's Rock Cress. Rocky soil, 4,500 to 6,000 feet, common.

Arabis Drummondii Gray, var. *connexa* (Greene) Fernald, Mt. Rainier, *Piper* 206x.

Arabis furcata Wats., Rocky slopes, fairly abundant.

Arabis glabra (L.,) Bernh., Smooth Rock Cress. Open places, rare, Allen, June 11, 1894.

Arabis hirsuta Scop., Hairy Rock Cress. Rocky soil, 2,500 to 5,000 feet, common.

Arabis Holboellii Hornem., Rock Cress. Gravelly soil, rare, White River, Warren 1472.

Arabis Lyallii Wats., Lyall's Rock Cress. Open hillsides, 4,500 to 8,500 feet, abundant.

Barbarea orthoceras Ledeb., var., *dolichocarpa* Fernald. Rocky soil, fairly common.

**Capsella Bursa-pastoris* (L.) Medic., Shepherds Purse. Gravelly soil, Longmire, Warren 1648; observed, Tipsoo Lake, September 1932.

Cardamine angulata Hook., Angular Bitter Cress. Moist woods, Upper Nisqually Valley, Allen 128.

Cardamine bellidifolia L., Bitter Cress. Burroughs Mountain, Flett 3155 in part.

Cardamine Breweri Wats., Brewer's Bitter Cress. Wet places, to 4,000 feet. rather rare.

Cardamine kamtschatica (Regel) Schulz, Bitter Cress. Moist places, 4,000 to 6,000 feet, abundant.

Cardamine occidentalis (Wats.) Howell, Bitter Cress. Wet places, Longmire, Flett 3500.

Cardamine oligosperma Nutt., Bitter Cress. Moist places, 4,500 to 6,000 feet, fairly common.

Cardamine pennsylvanica Muhl., Bitter Cress. Swampy places, rather rare.

Dentaria tenella Pursh, Toothwort. Moist woods, Upper Nisqually Valley, Allen 51.

Dentaria tenella Pursh, var. *pulcherrima* (Greene) Detling. Mt. Rainier, fide Detling.

Draba aureola Wats., Golden Mustard. Rocky soil, 9,000 to 10,000 feet, common.

Draba incerta Payson. Goat Island Mt., 7,000 feet, English, June 14, 1936.

Draba lonchocarpa Rydb., Whitlow Grass. Rare, Owyhigh, Flett, August 9, 1919.

Draba lonchocarpa Rydb., var. *semitonsa* Payson & St. John. Rocky places, 6,000 to 8,000 feet, common.

Draba novolympica St. John. Burroughs Mt., 7,000 feet, English 2539.

Draba ruaxes St. John. One-half mile northwest of Frozen Lake, Carl S. English, October 1, 1933.

Erysimum torulosum Piper, Mountain Wallflower. Rocky places, 5,000 to 6,500 feet, common.

**Lepidium campestre* L., Cow Cress. River bed, Ipsut Creek, Warren 1437.

Physaria alpestris Suksd., Bladder-pod. Rocky soil, Flett, July 20, 1899.

Rorippa curvisiliqua (Hook.) Bessey. Moist lake shore, Chenuis Lakes, Warren 820.

**Sisymbrium altissimum* L., Jim Hill Mustard. Waste places, Longmire, Warren 1629.

Sisymbrium incisum Engelm., var., *Hartwegianum* (Tourn.) Wats. Road sides, above Camp Ground, White River.

**Sisymbrium officinale* (L.) Scop., Hedge Mustard. Ohanapecosh, Warren 1893, not common.

Smelowskia ovalis Jones, Mountain Candy-tuft. Rocky places, 6,000 to 11,000 feet, abundant.

**Thlaspi arvense* L., Penny Cress. Waste places, Longmire, Warren 1581.

Thlaspi glaucum A. Nels. Rocky slopes, 4,000 to 6,000 feet, very common.

Crassulaceae

Sedum divergens Wats., Stone-crop. Rocky places, 4,000 to 6,000 feet, common.

Sedum integrifolium (Raf.) A. Nels., Purple Stone-crop. Fremont Mt., 7,000 feet, English in 1934.

Sedum oreganum Nutt., Oregon Stone-crop. Rocky places, rare, Nisqually Canyon, Warren 508.

Droseraceae

Drosera rotundifolia L., Sundew. Wet places, Longmire, Flett 4; Warren 629.

Saxifragaceae

Boykinia elata (Nutt.) Greene. Wet places, Allen 118; cited in Piper's "Flora of Washington," but material was not located.

Chrysosplenium glechomaefolium Nutt., Golden Saxifrage. Wet places, Allen 150, rare.

Heuchera glabra Willd., Smooth Alum Root. Rocky places, 5,000 to 7,000 feet, common.

Heuchera Nuttallii Rydb., Nuttall's Alum Root. Among rocks, Allen 10, rare.

Heuchera racemosa Wats., Alum Root. Rocky soil, 4,500 to 7,000 feet, common.

Leptarrhena amplexifolia (Sternb.) Ser. Wet places, 4,000 to 6,000 feet, abundant.

Mitella Breweri Gray, Brewer's Mitrewort. Among trees, 5,000 to 6,500 feet, common.

Mitella caulescens Nutt., Mitrewort. Moist woods, rather rare.

Mitella pentandra Hook., Bishops Cap. Moist places, 3,500 to 6,500 feet, abundant.

Mitella trifida Graham, Mitrewort. Rocky soil, 4,500 to 6,000 feet, common.

Parnassia fimbriata Koenig, Grass-of-Parnassus. Wet places, 4,000 to 6,000 feet, very abundant.

Philadelphus Lewisii Pursh, Syringa. Rocky places, Tum Tum, Allen 221; Ipsut Pass, Warren 884.

Ribes bracteosum Dougl., Stinking Curant. Along streams, 2,000 to 4,500 feet, abundant.

Ribes divaricatum Dougl., Wild Gooseberry. Wet places, Upper Nisqually Valley, Allen 69, rare.

Ribes Howellii Greene, Howell's Currant. Open slopes, 3,000 to 6,500 feet, very common.

Ribes lacustre (Pers.) Poir., Swamp Currant. Wet places, 2,000 to 5,000 feet abundant.

Ribes laxiflorum Pursh, Skunk Currant. Rocky soil, 2,500 to 6,000 feet, common.

Ribes Lobbii Gray, Lobb's Gooseberry. Rocky places, Upper Nisqually Valley, Allen 28, rare.

Ribes sanguineum Pursh, Flowering Currant. Open woods, not common.

Ribes viscosissimum Pursh, Sticky Currant. Sandy soil, 4,500 to 6,500 feet, known only from White River District.

Ribes Watsonianum Koehne, Watson's Gooseberry. Rocky soil, 4,500 to 5,500 feet, known only from White River District.

Saxifraga arguta D. Don, Saxifrage. Wet places, 2,500 to 6,000 feet, common.

Saxifraga austromontana Wiegand. Rocky places, 4,500 to 7,000 feet, quite common.

Saxifraga cespitosa L., Tufted Saxifrage. Rocky ledges, 5,000 to 7,000 feet, common.

Saxifraga debilis Engelm. On rock wall at Sluskin Falls, 6,000 to 7,000 feet, August 20, 1895, Allen.

Saxifraga ferruginea Graham, Saxifrage. Wet hillsides, 2,500 to 6,500 feet, common.

Saxifraga Mertensiana Bong., Mertens' Saxifrage. Wet rocky places, 5.000 to 6,500 feet, common.

Saxifraga occidentalis Wats., Western Saxifrage. Wet cliffs, 5,000 to 7,000 feet, quite common.

Saxifraga oppositifolia L., Purple Saxifrage. Burroughs. Mt. English 2538; Frying Pan Cr., 5,500 feet, English 2568.

Saxifraga Tolmiei T. & G., Tolmie's Saxifrage. Rocky soils, 5,500 to 9,000 feet, abundant.

Saxifraga vespertina Small. Rocky ledges, Mount Wow, Allen 197; Iron Mountain, Warren 573, rare.

Suksdorfia ranunculifolia (Hook.) Engler. Rocky slopes, 3,000 to 6,000 feet, fairly common.

Tellima grandiflora (Pursh) Dougl., Tellima. Moist places, quite common.

Tiarella trifoliata L., Coolwort. Moist places, abundant.

Tiarella unifoliata Hook., Coolwort. Moist woods, up to 5,000 feet, common.

Tolmiea Menziesii (Pursh) T. & G., Youth-on-Age. Moist places, 2,000 to 3,500 feet, abundant.

Rosaceae

Amelanchier florida Lindl., Service Berry. Open woods, rather rare.

Aruncus sylvester Kostel., Goats Beard. Moist places, observed, Stevens Canyon and Carbon River.

Dryas octopetala L., White Avens. Talus slope, rare, Flett, 2166.

Fragaria bracteata Heller, Strawberry. Sandy soil, White River, Warren 1488.

Fragaria chiloensis (L.) Duch., Strawberry. Sandy soils, rare, Stevens Crossing, Warren 1758.

Fragaria cuneifolia Nutt., Strawberry. Sandy soil, near Canyon Bridge, Warren 1762.

Fragaria Helleri Holz., Strawberry. Rare, Ohanapecosh River, Flett, 3118.

Fragaria platypetala Rydb., Strawberry. Sandy soil, Crystal Lake, R. A. Diettert; Sunrise Point, Warren, 1497, rare.

Geum macrophyllum Willd., Large-leaved Avens. Moist places, abundant.

Holodiscus discolor (Pursh) Maxim., Ocean Spray. Open slopes, rather rare.

Lutkea pectinata (Pursh) Kuntze, Alaska Spiraea. Alpine meadows, 3,000 to 6,000 feet, very abundant.

Osmaronia cerasiformis (T. & G.) Greene, Indian Plum. Moist open places, Upper Nisqually Valley, Allen 59.

Potentilla diversifolia Lehm., Cinquefoil. Rocky places, 5,500 to 7,000 feet, fairly common.

Potentilla flabellifolia Hook., Cinquefoil. Alpine meadows, 5,000 to 6,000 feet, very abundant.

Potentilla fruticosa L., Bushy Cinquefoil. Rocky places, 5,000 to 8,000 feet, fairly common.

Potentilla glandulosa Lindl., Cinquefoil. Dry rocky slopes, near Ipsut Pass, Warren 803.

Potentilla gracilis Dougl., Cinquefoil. Grassy places, Longmire, Warren 655.

Potentilla millegrana Engelm., Cinquefoil. Moist soils, Longmire, Warren 1692.

Potentilla norvegica L., var. *hirsuta* (Michx.) Lehm., Cinquefoil. Gravelly soil, Longmire, Warren 1568.

Potentilla palustris (L.) Scop., Swamp Cinquefoil. Wet places, Longmire, Flett 22; Warren 1616.

Potentilla villosa Pall., Hairy Cinquefoil. Rocky ledges, 5,000 to 7,000 feet fairly common.

Prunus emarginata (Dougl.) Walp., var. *mollis* (Dougl.) Brewer, Wild Cherry. Open woods, Upper Nisqually Valley, Allen 120; Mount Wow, Warren 1587.

Pyrus dumosa (Greene) Fern., Mountain Ash. Open woods, 4,000 to 6,000 feet, quite common.

Pyrus fusca Raf., Wild Crab Apple. Wet places, Tahoma Creek, Warren 1794; Kautz Cr. Bridge, Warren 1732.

Pyrus occidentalis Wats., Mountain Ash. Open slopes, 4,500 to 6,000 feet, common.

Rosa gymnocarpa Nutt., Wild Rose. Open woods, 3,500 to 5,000 feet, fairly common.

Rosa nutkana Presl, Wild Rose. Rocky soil, Mount Wow, Allen 292; Tipsoo Lake, Warren 1549.

Rosa Pringlei Rydb., Wild Rose. Wet places, Upper Nisqually Valley, Allen 123, Mount Wow, Warren 1610. G. N. Jones does not cite these specimens or dispose of the species which was accepted in Rydberg's monograph. Hence, we will maintain it tentatively.

**Rubus idaeus* L., var. *strigosus* (Michx.) Maxim., Raspberry. Edge of swamp, Longmire, Warren 1672. Probably introduced by the Longmire family, who homesteaded the area years ago.

Rubus laciniatus Willd., Evergreen Blackberry. Rocky soil, Longmire, Warren 1573.

Rubus lasiococcus Gray, Brambleberry. Open woods, 2,000 to 6,000 feet, abundant.

Rubus leucodermis Dougl., Black Cap. Rocky soil, 2,000 to 5,000 feet, common.

Rubus macropetalus Dougl., Wild Blackberry. Open woods and roadsides, uncommon.

Rubus nivalis Dougl., Shiny-leaved Bramble. Deep woods, 2,000 to 5,000 feet, fairly common.

Rubus parviflorus Nutt., var. *grandiflorus* Farw., Thimbleberry. Open woods, 2,000 to 4,000 feet, abundant.

Rubus pedatus Smith, Bird Foot Bramble. Open woods, 2,000 to 5,500 feet, very common.

Rubus spectabilis Pursh, Salmonberry. Wet places, 2,000 to 5,000 feet, very abundant.

Sanguisorba canadensis L., var. *latifolia* Hook., Burnet. Wet places, Lake George, R. A. Diettert, August 22, 1931.

Sibbaldia procumbens L., Sibbaldia. Rocky slopes, 5,000 to 7,000 feet, common.

Spiraea densiflora Nutt., Rosy Spiraea. Moist place, 2,500 to 6,000 feet, abundant.

Spiraea Douglasii Hook., Douglas' Spiraea. Wet place, near Kautz Creek Bridge, Warren 1731.

Spiraea Menziesii Hook., Menzies' Spiraea. Wet places, 2,500 to 6,000 feet, common.

Leguminosae

**Cytisus scoparius* (L.) Link, Scotch Broom. Rocky soil, ¼ mile below Tahoma Glacier, Warren 1754.

**Lathyrus latifolius* L., Perennial Pea. Gravelly soil, Longmire, Warren 1697.

Lathyrus Nuttallii Wats., Nuttall's Pea. Upper Nisqually Valley, Allen 297; Mount Wow, Warren 1614.

Lathyrus pauciflorus Fern., Large-flowered Pea. Rocky slopes, Upper Nisqually Valley, Allen 132.

Lupinus latifolius Agardh., var. *columbianus* (Heller) C. P. Smith, Lupine. Alpine meadows, 4,000 to 6,000 feet, very common.

Lupinus latifolius Agardh., var. *canadensis* C. P. Smith. Rocky soil, not common, White River, Warren 1445.

Lupinus Lyallii Gray, Lyall's Lupine. Rocky soil, 5,500 to 9,000 feet, very abundant.

Lupinus volcanicus Greene, Rainier Lupine. Volcanic soils, 5,000 to 8,000 feet, fairly common. Known only from Mount Rainier.

**Medicago lupulina* L., Black Medic. Gravelly soil, Longmire, Warren 1638.

**Medicago sativa* L., Alfalfa. Gravelly soil, Longmire, Warren 1706.

Oxytropis Mazama St. John, Mountain Locoweed. Rocky places, known only from Mount Wow.

**Trifolium dubium* Sibth., Hop Clover. Wet soil, Longmire, Warren 1653.

**Trifolium hybridum* L., Alsike Clover. Along the roadsides, Warren 1798, occasional.

**Trifolium pratense* L., Red Clover. Gravelly soil, Longmire, Warren 1620, not common.

**Trifolium repens* L., White Clover. Waste places, 2,000 to 6,000 feet, fairly common.

Vicia americana Muhl., Common Vetch. Moist rocky soil, 4,000 to 6,000 feet, fairly common.

Geraniaceae

**Geranium pusillum* Burm., Wild Geranium. Gravelly soil, Longmire, Warren 1571, not common.

Oxalidaceae

Oxalis oregana Nutt., Oregon Wood Sorrel. Deep woods, up to 3,000 feet, abundant.

Oxalis trilliifolia Hook., Wood Sorrel. Moist woods, 2,000 to 3,000 feet, fairly common.

Callitrichaceae

Callitriche autumnalis L., Water Star-wort. Shallow water, Reflection Lake, Warren 567, rare.

Callitriche palustris L., Water Star-wort. Shallow water, 2,000 to 5,500 feet, rather rare.

Empetraceae

Empetrum nigrum L., Crowberry. Rocky soil, 5,000 to 9,000 feet, common.

Celastraceae

Pachystima myrsinites (Pursh) Raf., Mountain Box. Open hillsides, 2,500 to 6,000 feet, very abundant.

Aceraceae

Acer circinatum Pursh, Vine Maple. Rocky places, 2,000 to 5,000 feet, common.

Acer Douglasii Hook., Douglas' Maple. Open woods, 2,000 to 3,000 feet, rather rare.

Acer macrophyllum Pursh, Broad-leafed Maple. Moist soils, 2,000 to 3,000 feet, fairly common.

Rhamnaceae

Ceanothus sanguineus Pursh, Buckbrush. Open woods, Upper Nisqually Valley, Allen 111, rare.

Ceanothus velutinus Dougl., Sticky Laurel. Open woods, White River District, J. M. Grant; R. A. Diettert.

Malvaceae

**Malva rotundifolia* L., Cheeses. Gravelly soil, Longmire, Warren 1630, uncommon.

Hypericaceae

Hypericum anagalloides C. & S., St. John's Wort. Wet places, 2,700 to 6,000 feet, common.

Violaceae

Viola adunca Smith, Purple Violet. Grassy slopes, 5,000 to 6,000 feet, common.

Viola adunca Smith, f. *glabra* (Brainerd) G. N. Jones, Purple Violet. Grassy slopes, 5,000 to 7,000 feet, fairly common.

Viola glabella Nutt., Yellow Violet. Moist places, 2,000 to 5,500 feet, very common.

Viola orbiculata Geyer, Round-leaved Yellow Violet. Moist woods, not common.

Viola pallens (Banks) Brainerd, Little White Violet. Wet places, Snipes Lake, (White River District) Flett, rare.

Viola palustris L., Purple Swamp Violet. Wet places, 2,700 to 5,000 feet, common.

Viola purpurea Kellogg, var. *venosa* (Wats.) Brainerd, Violet. Rocky soil, near Tipsoo Lake, Warren 1571, rare.

Viola sempervirens Greene, Evergreen Violet. Open woods, 2,000 to 4,000 feet, very common.

Onagraceae

Circaea alpina L., var. *pacifica* (Aschers. & Magnus) M. E. Jones, Enchanters Night Shade. Moist soils, 2,000 to 4,000 feet, very common.

Epilobium alpinum L., Alpine Willow Herb. Wet places, 4,000 to 6,500 feet, very common.

Epilobium angustifolium L., Fire-weed. Open hilsides, 2,000 to 6,000 feet, common.

Epilobium glaberrimum Barbey, var. *latifolium* Barbey. Rocky soil, 2,000 to 6,000 feet, common.

Epilobium glandulosum Lehm., var. *occidentale* (Trel.) Fernald. Open places, very common.

Epilobium Hornemanni Reichenb., Willow Herb. Wet places, 4,000 to 6,000 feet, fairly common.

Epilobium latifolium L., Water Willow Herb. Wet places, 3,000 to 6,000 feet, Nickel creek, Flett 3042.

Epilobium luteum Pursh. Wet places, 3,000 to 6,000 feet, very common.

Epilobium minutum Lindl., Willow Herb. Open woods, rather rare.

Epilobium paniculatum Nutt., f. *adenocladon* Haussk., Willow Herb. Open woods, Upper Nisqually Valley, Allen 14, rare.

Epilobium pulchrum Suksd., Willow Herb. Wet banks, Piper 2168.

Gayophytum ramosissimum T. & G. Dry soil, 2,000 to 5,500 feet, fairly common.

Haloragidaceae

Hippuris montana Ledeb., Mountain Mare's Tail. Wet places, 4,500 to 6,500 feet, very common.

Hippuris vulgaris L., Mare's Tail. Shallow water, Swamp at Longmire, Piper, August 1895; Warren 610, rare.

Araliaceae

Oplopanax horridum (Smith) Miquel, Devil's Club. Wet places, 2,000 to 3,000 feet, very abundant.

Umbelliferae

Angelica genuflexua Nutt., Angelica. Wet places, Upper Nisqually Valley, Allen 36, rare.

Angelica Lyallii Wats., Lyall's Angelica. Wet places, 2,500 to 5,500 feet, common.

Cicuta vagans Greene, Water Hemlock. Swampy places, Upper Nisqually Valley, Allen 255, rare.

Cogswellia angustata C. & R., Hog Fennel. Rocky places, 2,500 to 6,500 feet, very abundant.

Cogswellia brevifolia (C. & R.) M. E. Jones, Hog Fennel. Open slopes, 3,000 to 5,500 feet, rather rare.

Heracleum lanatum Michx., Cow Parsnip. Moist places, 2,000 to 5,500 feet, common.

Hesperogenia Stricklandi C. & R., Strickland's Parsley. Grassy meadows, 5,000 to 6,500 feet, fairly common.

Ligusticum purpureum C. &. R., Lovage. Alpine meadows, 5,000 to 6,500 feet, very common.

Ligusticum tenuifolium Wats., Lovage. Alpine meadows, 5,500 to 6,500 feet, fairly common.

Oenanthe sarmentosa Presl., Water Celery. Swamps, Upper Nisqually Valley, Allen 35; Longmire, Warren 594.

Osmorhiza ambigua (Gray) C. & R., Sweet Cicely. Rocky slopes, 4,500 to 5,500 feet, quite common.

Osmorhiza brevipes (C. & R.) Suksd., Sweet Cicely. Open woods, rare, Ohanapecosh, Flett 3179.

Osmorhiza divaricata (Britton) Robins. & Fern., Sweet Cicely. Woods, 2,000 to 3,000 feet, very common.

Osmorhiza Leibergii (C. & R.) Blankinship. Rocky soil, 3,000 to 5,800 feet, rare.

Sanicula septentrionalis Greene, Western Sanicle. Dry rocky slopes, Mount Wow, Allen 254; Warren 1727, rare.

Cornaceae

Cornus canadensis L., Canadian Dogwood. Open woods, 2,000 to 3,500 feet, very abundant.

Cornus Nuttallii Audubon, Western Dogwood. Open woods, Upper Nisqually Valley, Allen 208; Ohanapecosh, Warren observed, 1933, rare.

Cornus stolonifera Michx., Osier Dogwood. Wet places, Longmire, Flett 3310, rare.

Ericaceae

Allotropa virgata T. & G., Barber's Pole. Dry woods, Ohanapecosh, Flett, 3132; Tahoma Creek, Warren 1780, rare.

Arctostaphylos nevadensis Gray, Bearberry. Open slopes, 2,500 to 6,500 feet, fairly common.

Arctostaphylos tomentosa (Pursh) Lindl., Bearberry. Ohanapecosh, Warren 1895, not typical.

Arctostaphylos Uva-ursi (L.) Spreng., Bearberry. Rocky places, 5,000 to 8,000 feet, fairly common.

Cassiope Mertensiana (Bong.) G. Don, White Heather. Open slopes, 4,500 to 6,500 feet, very abundant.

Chimaphila Menziesii (R. Br.) Spreng., Menzies' Pipsissewa. Deep woods, 2,200 to 4,000 feet, common.

Chimaphila umbellata (L.) Bart., var. *occidentalis* (Rydb.) Blake. Open woods, 2,000 to 5,000 feet, very common.

Gaultheria humifusa (Graham) Rydb., Creeping Salal. Open slopes, 4,000 to 6,000 feet, common.

Gaultheria ovatifolia Gray, Red-berried Salal. Open woods, 3,000 to 4,500 feet, very abundant.

Gaultheria Shallon Pursh, Salal. Open woods, 2,000 to 4,500 feet, common.

Harrimanella Stelleriana (Pall.) Cov., White Heather. Moist slopes, 5,000 to 7,000 feet, very abundant.

Hemitomes congestum Gray, Cone-plant. Woods, Ohanapecosh, Flett 3145; Ipsut Creek, observed, 1931.

Kalmia polifolia Wang., Sheep Laurel. Wet places, Upper Nisqually Valley, Allen 4; Mountain Meadows, Warren 821, rather rare.

Kalmia polifolia Wang., var. *microphylla* (Hook.) Rehder. Wet slopes, 5,000 to 7,000 feet, very common.

Ledum groenlandicum Oeder, Labrador Tea. Wet places, Longmire, Flett, 12; Warren 774, rare.

Menziesia ferruginea Smith, Fool's Huckleberry. Open woods, 2,000 to 3,000 feet, very common.

Monotropa Hypopitys L., Many-flowered Indian Pipe. Deep woods, quite common.

Monotropa uniflora L., Indian Pipe. Deep woods, Upper Nisqually Valley, Piper; Tahoma Creek Bridge, observed, August 1932.

Phyllodoce empetriformis (Smith) D. Don, Red Heather. Open slopes, 4,500 to 6,500 feet, very abundant.

Phyllodoce glandulifera (Hook.) Cov., Yellow Heather. 5,500 to 8,000 feet, common.

Pterospora andromedea Nutt., Pinedrops. Deep woods, 2,000 to 4,500 feet, fairly common.

Pyrola aphylla Sm., Pyrola. Mossy woods, Ohanapecosh, Flett 3133.

Pyrola bracteata Hook., Pink Pyrola. Open woods, 2,000 to 4,000 feet, common.

Pyrola chlorantha Sw., Green Pyrola. Deep woods, Allen July 21, 1894; Upper Tahoma Creek, Warren 1713, rare.

Pyrola dentata Smith, Pyrola. Mossy woods, 2,000 to 4,000 feet, common.

Pyrola minor L., Small Pyrola. Woods, 2,500 to 3,500 feet, rather rare.

Pyrola secunda L., One-sided Pyrola. Deep woods, 2,500 to 5,500 feet, common.

Pyrola uliginosa T. & G., Pyrola. Wet woods, Ohanapecosh, Flett 3134, rare.

Pyrola uniflora L., var. *reticulata* (Nutt.) St. John, Single Beauty. Mossy woods, 2,000 to 3,000 feet, rather rare.

Rhododendron albiflorum Hook., White Rhododendron. Open woods, 5,000 to 6,500 feet, very abundant.

Vaccinium deliciosum Piper, Mountain Blueberry. Alpine meadows, 4,500 to 6,500 feet, very common.

Vaccinium membranaceum Dougl., Black Huckleberry. Open woods, 2,000 to 4,500 feet, common.

Vaccinium ovalifolium Smith, Oval-leaved Huckleberry. Open woods, 2,000 to 4,500 feet, very common.

Vaccinium ovatum Pursh, Evergreen Huckleberry. Open woods, observed July 1931, rather rare.

Vaccinium Oxycoccus L., var. *ovalifolium* Michx., Wild Cranberry. Reported by Len Longmire, (August 1932) as growing in swamp at Longmire and near Bear Prairie Point, nearly forty years ago. It is quite likely that

Cranberries were found in some portions of the Park. The writers would appreciate any other information as to Cranberries growing in the area.

Vaccinium scoparium Leiberg, Red Whortle Berry. Sandy soil, 4,500 to 6,000 feet, common.

Primulaceae

Dodecatheon Jeffreyi Van Houtte. Wet places, 4,500 to 6,500 feet, very common.

Douglasia laevigata Gray, Mountain Pink. Rocky ledges, Mount Wow, Allen 187; Iron Mountain, Warren 577, rare.

Trientalis arctica Fisch., Swamp Star-flower. Wet places, Longmire, Allen 20; Flett 3306.

Trientalis latifolia Hook., Star-flower. Woods, 2,000 to 5,000 feet, fairly common.

Gentianaceae

Gentiana calycosa Griseb., Blue Gentiana. Alpine meadows, 5,000 to 7,500 feet, very abundant. White flowered forms are occasionally found.

Menyanthes trifoliata L., Buck-bean. Swamps, Longmire, Warren 630, rare.

Apocynaceae

Apocynum androsaemifolium L., Dog-bane. Dry soil, Nickel Creek, Warren 606; Ricksecker Point Road, Warren 650.

Polemoniaceae

Collomia heterophylla Hook., Collomia. Dry soil, about Longmire, fairly common.

Collomia Larsenii (Gray) Payson, Larsen's Collomia. Dry rocky soils, 6,000 to 8,000 feet, common.

Gilia capitata Hook., Blue Gilia. Open places, Ohanapecosh, Flett 3314; Longmire, observed, 1926, rare.

Gilia gracilis Hook., Gilia. Dry soil, fairly common.

Gilia humilis (Greene) Piper, Gilia. Rocky soil, Tipsoo Lake, Warren 1651, rare.

Gilia Nuttallii Gray, Nuttall's Gilia. Grassy slopes, 5,000 to 6,000 feet, very common.

Phlox cespitosa Nutt., Mountain Phlox. Grassy slopes, 5,000 to 7,000 feet, common.

Polemonium elegans Greene, Small Greek Valerian. Rocky places, 5,500 to 9,000 feet, abundant.

Polemonium delicatum Rydb. Dry slopes, 5,000 to 7,000 feet, common.

Polemonium pilosum (Greenm.) G. N. Jones. Rocks, Mount Wow, Allen 261; Warren 788, rare.

Hydrophyllaceae

Hydrophyllum congestum Wiegand, Water Leaf. Moist soils, 4,000 to 6,000 feet, common.

Hydrophyllum tenuipes Heller, Water Leaf. Moist woods, Tahoma Creek, Warren 595.

Nemophila parviflora Dougl., Grove-lover. Shady places, Upper Nisqually Valley, Allen 61, rare.

Phacelia circinata Jacquin. Piper wrote, "a form of this variable plant occurs on talus along north side of Cowlitz Glacier," Mazama 2: 101. Probably the same as P. heterophylla Pursh var., griseophylla (Brand) Macbride.

Phacelia heterophylla Pursh, var. *griseophylla* (Brand) Macbride. Rocky soils, 4,500 to 6,500 feet, quite common.

Phacelia nemoralis Greene, var. *mutabilis* (Greene) Macbride. Rocky soil, 2,000 to 5,000 feet, abundant.

Phacelia sericea (Graham) Gray, Purple Phacelia. Rocky places, Burroughs Mountain, J. M. Grant; Puyallup Glacier, Flett 265.

Romanzoffia sitchensis Bong., Mist Maiden. Wet rocks, Mount Wow, Allen 236; north side, Flett 229.

Boraginaceae

**Amsinckia* sp. Gravelly soil; near Longmire, Warren 1582.

Cryptantha muriculata (A. DC.) Greene. Sandy soil, White River, Warren 1449, rare.

Mertensia paniculata (Ait.) G. Don, var. *laevigata* (Piper) G. N. Jones, Blue Bells. Moist places, 4,000 to 6,000 feet, very abundant.

Labiatae

**Lamium amplexicaule* L., Dead Nettle. Gravelly soil, Longmire, Warren 1639, not common.

Mentha arvensis L., var. *glabrata* (Benth.) Fernald, Mint. Wet places, Longmire, Flett 1.

**Mentha citrata* Ehrh. Gravelly soil, uncommon, Longmire, Warren 1699.

Monardella odoratissima Benth., var., discolor (Greene) St. John. Rocky soil, Cowlitz Glacier, Piper 2078; Emmons Glacier, J. M. Grant.

**Nepeta Cataria* L., Cat-nip. Ohanapecosh, near ranger station, Warren 1895.

Prunella vulgaris L., var. *lanceolata* (Barton) Fernald, Heal All. Moist places, Longmire, Warren 1636.

Satureja Douglasii (Benth.) Briq., Yerba Buena. Open woods, fairly common.

Stachys ciliata Dougl., Hedge Nettle. Wet places, Upper Nisqually Valley, Allen 131.

Solanaceae

**Solanum nigrum* L., Night Shade. Gravelly soil, Longmire, Warren 1517, rare.

Scrophulariaceae

Castilleja angustifolia (Nutt.) G. Don, var. *hispida* (Benth.) Fernald. Dry rocky slopes, Sluskin Falls, Warren 452.

Castilleja indecora Piper, Yellow Paint Brush. Wet meadows, 5,500 to 6,000 feet, fairly common.

Castilleja levisecta Greenm., Paint Brush. Open meadows, J. M. Grant, August 1925.

Castilleja miniata Dougl., Red Paint Brush. Grassy slopes, 4,500 to 6,000 feet, very common.

Castilleja oreopola Greenm., Scarlet Paint Brush. Alpine meadows, 5,000 to 6,500 feet, common.

Castilleja rupicola Piper, Rock Paint Brush. Rocky places, 4,500 to 6,500 feet, common.

Collinsia parviflora Lindl., Blue-lip. Rocky slopes, 4,500 to 6,000 feet, fairly common.

**Digitalis purpurea* L., Fox Glove. Moist soil, Longmire, Warren 1597; Carbon River, observed 1931.

Mimulus alsinoides Dougl., Monkey Flower. Rocky soil, 3,500 to 5,000 feet, common.

Mimulus Breweri (Greene) Coville. Rocky slopes, 4,500 to 6,000 feet, common.

Mimulus guttatus DC., Tall Monkey Flower. Wet places, 2,000 to 5,500 feet, fairly common.

Mimulus Lewisii Pursh, Lewis' Monkey Flower. Alpine meadows, 2,500 to 6,500 feet, very common. A large white-flowered clump of this species has been found near the trail in Seattle Park.

Mimulus moschatus Dougl., Musk Flower. Wet places, 2,500 to 4,000 feet, fairly common.

Mimulus Tilingi Regel, Alpine Monkey-flower. Wet places, 2,000 to 6,500 feet, very abundant.

Pedicularis latifolia Pennell, Indian Warrior. Moist slopes, 5,000 to 6,500 feet, very common.

Pedicularis contorta Benth., Alpine Lousewort. Alpine meadows, 4,500 to 7,000 feet, very common.

Pedicularis groenlandica Retz., Elephant-head Lousewort. Wet places, 4,000 to 6,000 feet, fairly common.

Pedicularis ornithorhynca Benth., Duck-bill Lousewort. Moist places, 4,500 to 6,500 feet, very common.

Pedicularis racemosa Dougl., Common Lousewort. Alpine slopes, 4,000 to 6,500 feet, very common.

Pedicularis rainierensis Pennell & Warren, Mount Rainier Lousewort. Alpine meadows, 4,500 to 6,500 feet. Known only from Mount Rainier.

Penstemon confertus Dougl. Dry slopes, 5,000 to 7,000 feet common.

Penstemon diffusus Dougl., Beard Tongue. Rocky slopes, 3,000 to 6,000 feet, very abundant.

Penstemon fruticosus (Pursh) Greene, Lavender Beard Tongue. Rocky soils, White River, above camp grounds, Warren 1495; also reported growing near Canyon Rim, of the Nisqually District.

Pentstemon hesperius Peck, Blue Pentstemon. Gravelly soil, near Longmire, Warren 1674. This apparently is the first record for the State of Washington.

Pentstemon Menziesii Hook., Menzies' Beard Tongue. Rocky soil, 3,000 to 7,500 feet, common.

Penstemon nemorosus (Dougl.) Trautv., Turtlehead. Rocky places, 2,000 to 7,000 feet, very abundant.

Pentstemon ovatus Dougl., Beard Tongue. Rocky hillsides, Upper Nisqually Valley, Allen 16.

Pentstemon rupicola Howell, Red Pentstemon. Rocky slopes, 2,500 to 6,000 feet, very common.

Pentstemon Tolmiei Hook. Rocky hillsides, 5,000 to 6,000 feet, fairly common.

**Verbascum Thapsus* L., Mullein. Introduced weed, Longmire, observed, 1932.

Veronica americana Schwein., American Speedwell. Wet places 2,000 to 5,500 feet, fairly common.

Veronica arvensis L., Speedwell. Moist places, Longmire, Warren 643, rare.

Veronica Cusickii Gray, Cusick's Speedwell. Grassy slopes, 5,500 to 6,500 feet, very abundant.

Veronica Cusickii Gray, var. *Allenii* (Greenm.) Macbride. Moist places, 4,500 to 6,000 feet, fairly common.

Veronica humifusa Dickson, Speedwell. Moist places, Longmire Warren 562.

Veronica peregrina L., var. *xalapensis* (H.B.K.) St. John & Warren. Gravelly soil, Longmire, Warren 1572, fairly common.

Veronica scutellata L., Speedwell. Wet places, Upper Nisqually Valley, Allen 228; White River, J. M. Grant.

Veronica Wormskjoldii R. & S., Alpine Speedwell. Moist places, 4,500 to 6,500 feet, common.

Orobanchaceae

Orobanche uniflora L., var. *minuta* (Suksd.) G. Beck, Broom-rape. Moist soils, Canyon Bridge, Warren 653 and 1774.

Lentibulariaceae

Pinguicula vulgaris L., Butterwort. Wet places, 3,000 to 6,000 feet, fairly common.

Plantaginaceae

**Plantago lanceolata* L., Buckthorn Plantain. Gravelly soil, Longmire, Warren 1655, common.

**Plantago major* L., Common Plantain. Moist places, Longmire, Warren 1654.

Rubiaceae

Galium cymosum Wiegand, Bed Straw. Grassy places, Longmire, Warren 640.

Galium oreganum Britt., Oregon Bed-straw. Open woods, 2,500 to 6,000 feet, common.

Galium trifidum L., Bedstraw. Wet places, 2,000 to 3,500 feet, common.

Galium triflorum Michx., Sweet Bedstraw. Moist woods, 2,000 to 5,500 feet, common.

Caprifoliaceae

Linnaea borealis L., var. *longiflora* Torr., Twin Flower. Open woods, 2,000 to 4,000 feet, quite common.

Lonicera ciliosa (Pursh) Poir., Honeysuckle. Open woods, Upper Nisqually Valley, Allen 113; Canyon Bridge, Warren 1761.

Lonicera involucrata (Richards) Banks, Black Twinberry. Wet places, 2,000 to 4,500 feet, common.

Sambucus glauca Nutt., Blue Elderberry. Open woods, Upper Nisqually Valley, Allen 302; Longmire, Warren 1578.

Sambucus leiosperma Leiberg, Red Elderberry. Moist places, 2,000 to 5,000 feet, common.

Symphoricarpos albus (L.) Blake, var. *mollis* (Nutt.) Keck., Snowberry. Rocky hillsides, Upper Nisqually Valley, Allen 105; Mount Wow, Warren 1717.

Viburnum pauciflorum Raf., High Bush Cranberry. Wet places, Mountain Meadows, Flett 3079; Ohanapecosh, Flett 3080.

Valerianaceae

Valeriana sitchensis Bong., Valerian. Moist slopes, 3,000 to 6,500 feet, very abundant.

Campanulaceae

Campanula rotundifolia L., Bluebell. Rocky slopes, 3,000 to 6,500 feet, common.

Campanula Scouleri Hook., Scouler's Bell-flower. Open ground, 2,000 to 4,000 feet, common.

Compositae

Achillea Millefolium L., Common Yarrow. Open places, 2,000 to 5,000 feet, very common.

Achillea Millefolium L., var. *alpicola* (Rydb.) Garrett. Dry rocky soil, Panorama Point, Warren 581.

Achillea Millefolium L., var. *fusca* (Rydb.) G. N. Jones, Yarrow. Rocky slopes, Iron Mountain, Warren, 1589.

Adenocaulon bicolor Hook., Silver-green. Open woods, 2,000 to 6,500 feet, common.

Agoseris alpestris (Gray) Greene, Mountain Dandelion. Grassy slopes, 5,000 to 6,500 feet, very common.

Agoseris villosa Rydb. Rocky soil, 5,000 to 7,000 feet, fairly common.

Agoseris gracilens (Gray) Kuntze, Goat Chicory. Grassy slopes, 5,000 to 6,500 feet, common.

Agoseris laciniata (Nutt.) Greene. Dry slopes, Upper Nisqually Valley, Allen 225.

Anaphalis margaritacea (L.) B. & H., var., *occidentalis* Greene. Open places, 2,000 to 6,000 feet, common.

Antennaria candida Greene. Rocky soil, Allen 141.

Antennaria concolor Piper, Ladies Tobacco. Open woods, Mount Wow, Warren 1607.

Antennaria lanata (Hook.) Greene, Ladies' Tobacco. Rocky soil 5,000 to 7,000 feet, common.

Antennaria racemosa Hook. Open slopes, Upper Nisqually Valley, Allen 224.

Antennaria rosea Greene, Ladies' Tobacco. Rocky slopes, 4,000 to 7,000 feet, fairly common.

**Anthemis arvensis* L., Corn Chamomile. Waste places, Longmire, Warren 1698.

Apargidium boreale (Bong.) T. & G., Mountain Dandelion. Moist grassy slopes, 4,000 to 6,000 feet, common.

**Arctium minus* (Hill.) Bernh., Burdock. Ohanapecosh, roadside, Warren 1891.

Arnica aspera Greene, Arnica. Moist slopes, 5,000 to 6,000 feet, fairly common.

Arnica amplexicaulis Nutt., Arnica. Wet places, 2,000 to 6,000 feet, common.

Arnica betonicaefolia Greene. Alpine meadows, 5,000 to 6,000 feet, common.

Arnica cordifolia Hook., Arnica. Open woods, 4,000 to 6,000 feet, common.

Arnica diversifolia Greene. Dry slopes, Owyhigh, Flett 3199.

Arnica gracilis Rydb., Arnica. Owyhigh, Flett 3214.

Arnica latifolia Bong., Arnica. Open woods, 4,500 to 6,000 feet, common.

Arnica Macounii Greene, Macoun's Arnica. Rocky places, 2,000 to 6,000 feet, rare.

Arnica mollis Hook. Moist places, 4,000 to 6,500 feet, common.

Arnica myriadenia Piper, Owyhigh, Flett 3211; Glacier Basin, G. N. Jones, 133.

Arnica Parryi Gray, Parry's Arnica. Alpine meadows, 5,000 to 6,500 feet, abundant.

Arnica pumila Rydb. Talus, Burroughs Mountain, Flett 3219.

Arnica Rydbergii Greene, Rydberg's Arnica. Mount Wow, Allen 229.

Artemisia borealis Pall., var. *spithamea* (Pursh) T. & G. Glacier Basin, J. M. Grant, August 1925; Burnt Park, R. A. Diettert, July 23, 1931.

Artemisia norvegica Fries, subsp. *heterophylla* (Besser) H. & C. From 5,500 to 7,500 feet, fairly common.

Artemisia norvegica Fries, subsp. *saxatilis* (Besser) H. & C. Grassy slopes, 5,500 to 6,500 feet, Tolmie Peak, Warren 809.

Artemisia vulgaris L., subsp. *Gnaphalodes* (Nutt.) H. &. C. Rocky soil, 5,000 to 6,000 feet, fairly common.

Artemisia vulgaris L., subsp. *Tilesii* (Ledeb.) H. & C., Sage. Rocky places, Inter Fork, J. M. Grant.

Aster foliaceus Lindl., var. *apricus* Gray, Aster. Moist slopes, 4,000 to 6,000 feet, Smith, August 11, 1889; Van Trump Creek, Warren 634.

Aster foliaceus Lindl., var. *frondeus* Gray. Wet places, 4,000 to 6,000 feet, common.

Aster ledophyllus Gray, Aster. Alpine meadows, 5,000 to 6,500 feet, common.

Aster modestus Lindl., Aster. Wet places, 2,500 to 6,000 feet, fairly common.

Aster pulchellus D. C. Eaton, Aster. Moist slopes, 5,000 to 7,000 feet, abundant.

**Bidens frondosa* L., Beggar's Tick. Ohanapecosh, woodside, Warren 1896.

**Centaurea nigra* L., Black Knapweed. White River Camp, J. M. Grant, August 1925.

**Chrysanthemum Leucanthemum* L., var. *pinnatifidum* Lecoq & Lamotte. Moist soil, Longmire,, Warren 1657.

**Cirsium arvense* (L.) Scop., Canadian Thistle. Waste places, near Longmire, Warren 1564.

Cirsium edule Nutt., Edible Thistle. Rocky soils, 5,000 to 6,000 feet, common.

**Cirsium lanceolatum* (L.) Hill, Bull Thistle. Moist meadow, Longmire, Warren 1745.

**Crepis capillaris* (L.) Wallr., Hawks-beard. Gravelly soil, Longmire, Warren 1640.

Erigeron acris L., var. *debilis* Gray, Fleabane. Rocky soil, 5,500 to 7,000 feet, abundant.

Erigeron acris L., var. *asteroides* (Andrz.) DC. Sandy soil, near Longmire, Warren 1569, rare.

Erigeron canadensis L., Fleabane. White River Road, Grant August 1925.

Erigeron compositus Pursh, var. *multifidus* (Rydb.) Macbr. & Pays. Rocky soil, 5,500 to 7,000 feet, very common.

Erigeron philadelphicus L., Fleabane. Open woods, Ohanapecosh, Flett 3248; Warren 604.

Erigeron salsuginosus (Richards.) Gray, Mountain Daisy. Moist places 2,500 to 7,000 feet, very common.

Erigeron salsuginosus (Richards.) Gray, var. *angustifolius* Gray, Burrough's Mountain, Flett 3202.

Erigeron salsuginosus (Richards.) Gray, var. *glacialis* (Nutt.) Gray. Allen 142.

Erigeron speciosus DC., Fleabane. Open slopes, Upper Nisqually Valley, Allen 222.

Erigeron subtrinervis Rydb., Fleabane. Rocky soil, rare, Mount Wow, Warren 1726.

Eriophyllum lanatum (Pursh) Forbes, Wooly Daisy. Rocky slopes, 3,000 to 5,000 feet, not common.

Gnaphalium thermale E. Nels., Cudweed. Open ground, Upper Nisqually Valley, Allen 223.

Haplopappus Brandegei Gray, Golden Aster. Rocky soil, 5,500 to 8,000 feet, very common.

Haplopappus Lyallii Gray. Rocky soil, Burrough's Mountain, Flett 3230; Grant, August 1925.

Hieracium albiflorum Hook., White Hawkweed. Open slopes 2,000 to 6,500 feet, common.

Hieracium Cusickii Gdgr., Hawkweed. Rocky slopes, Owyhigh, Flett 3216; near Tipsoo Lake, Warren 1555.

Hieracium cynoglossoides Arvet-Touvet, Hawkweed. Crystal Lake, R. A. Diettert.

Hieracium Flettii St. John & Warren, Flett's Hawkweed. Rocky slopes, Indian Henry's, Warren 626, 772, 1715.

Hieracium gracile Hook., Hawkweed. Moist slopes, 4,000 to 7,000 feet, common.

Hulsea nana Gray. Pumice soil, 6,000 to 9,000 feet, rare.

**Hypochaeris radicata* L., Cat's Ear. Gravelly river bed, Ipsut Creek, Warren 1468.

Lactuca spicata (Lam.) Hitchc., Tall Blue Lettuce. Upper Nisqually Valley, Allen 126a, near Lake Allen trail, Warren, 1565.

**Lapsana communis* L., Nipplewort. Open woods, Ohanapecosh, Warren 605.

Luina hypoleuca Benth., Luina. Rocky soil 2,500 to 6,000 feet, very common.

Madia exigua (Smith) Gray, Tarweed. Hillsides, Canyon Bridge, Warren 652.

Matricaria Matricaroides (Less.) Porter, Pineapple Weed. Waste places, Longmire, Warren 1624.

Petasites nivalis Greene, Sweet Colt's Foot. Wet places, 4,500 to 6,000 feet, very common.

Petasites speciosa (Nutt.) Piper, Colt's Foot. Wet places, 2,000 to 4,000 feet, fairly common.

Prenanthes hastata (Less.) M. E. Jones, Rattlesnake Root. Rocky soil, Carbon River, Warren 833.

Rainieria stricta Greene, Rainieria. Dry slopes, 4,000 to 6,000 feet, common especially in White River area.

Saussurea americana D. C. Eaton, Saw-wort. Alpine meadows, 5,000 to 6,500 feet, fairly common.

Senecio columbianus Greene, Ragwort. Talus, Owyhigh, Flett 3260.

Senecio Flettii Wiegand, Flett's Ragwort. Talus slopes, 6,000 to 7,000 feet, rather rare.

Senecio Fremontii T. & G., Fremont's Ragwort. Rocky soil, 6,000 to 8,000 feet, common.

Senecio indecorus Greene, Moist places, Longmire, Warren 657.

Senecio integerrimus Nutt., Ragwort. Rocky slopes, 5,000 to 6,500 feet, common in White River District.

Senecio subnudus DC., Ragwort. Glacier Basin, July 25, 1931, R. A. Diettert.

Senecio Suksdorfii Greenm., Suksdorf's Ragwort. Rock slopes, Indian Henry's.

Senecio triangularis Hook., Arrowhead Ragwort. Wet places, 2,500 to 6,500 feet, common.

Senecio vulgaris L., Ragwort. Waste ground, Nisqually Canyon, Warren 457; Carbon River, R. A. Diettert.

Solidago ciliosa Greene, Golden-rod. Sandy soil, 5,500 to 6,500 feet, common.

Solidago lepida DC., var. *elongata* (Nutt.) Fern., Golden-rod. Upper Nisqually Valley, Allen 13; Nisqually Entrance, Warren, 1736.

**Sonchus asper* (L.) Hill, Sow Thistle. Waste places, Longmire, Warren 1626.

**Taraxacum vulgare* (Lam.) Schrank, Dandelion. Waste places, Longmire, observed, 1932.

**Tragopogon porrifolius* L., Salsify. Meadow, Longmire, Warren 1740.

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Plants as Indicators of Climate in Northeast Mexico

Cornelius H. Muller

Lack of any suitable detailed classification of the various climates of the Sierra Madre Oriental in Nuevo Leon, Mexico has led the author to attempt a differentiation of them based upon the distrbution of plants. Only the method employed and some illustrative applications are presented here.

Thornthwaite (1931) has mapped North America climatologically from data collected in meteorological observatories. His method of computing climatic values for the area lying between two observatories is to average the data of the two known loci with no seeming regard for physiographic features lying between, which might (and in many cases do!) profoundly influence the climate of the intervening area. Such apparently was the reason why the climate of the Sierra Madre Oriental was designated by him to be the same as that of the surrounding plains and foothills from which were taken the only available data.

Methods apparently similar to those of Thornthwaite led Sanchez (1929) to place all the mountain areas of Nuevo Leon under a single climatic type which he designated as "clima de estepas" (steppe climate) and which also includes a large part of the extensive Chihuahua Desert.

Page (1929) recognized the error of regarding the available data as sufficient and attempted to compensate for the deficiency by allowing altitude to enter as a factor in his calculations. This, in general, proved quite successful except where one encounters the rainshadow phenomenon which is discussed below.

Treatments less accurate than Page's as well as fragmentary descriptions occurring in both technical and popular literature have led to some erroneous generalizations concerning the nature of various little known lands. Mexico with its reputation for burning deserts and tropical forests is an excellent example. So deep-rooted have these ideas become that even the widely published illustrations of snow-clad *Popocatepetl* have failed to end the misconception that all Mexico is tropical. Even less generally known is the fact that *many* parts of Mexico are definitely alpine and subalpine in climate. These areas are of great interest to ecologists, and their study will sooner or later dispel the idea that the entire area is relatively homogeneous and tropical. With the realization that the international boundary is not also a climatic and biological boundary, biologists find the problems of distribution somewhat more complicated.

Clements (1920) has made wide application of the indicator value of plants in determining the nature of a habitat. His work includes indicators

of the physical and chemical nature of the soil, soil moisture, etc. Merriam (1894) recognized the responses of plants and animals to temperature gradients. His map of the state of Nuevo Leon is, from the standpoint of plant distribution, by far the most accurate yet seen by this author, though it leaves much to be desired. Long before either Clements or Merriam, however, various laymen, particularly woodsmen, realized the correlation between a favorable climate and luxuriant forest growth. Scientific workers, in their zeal for accuracy, have tended to become too detailed in their claims for the indicator value of plants. Clements (1920, p. 28) points out the generally accepted fact that plant distribution is the product of the entire habitat. No one factor, whether temperature, moisture, or soil, can be held strictly responsible for the entire distribution of any one species of plant or type of plant cover. Shantz (1911) presents data which demonstrate this graphically. He points out the fact that, although in the western extremities of the Great Plains the bunch-grass prairie is confined to sandy soil, the fine-textured soils in that area bear only short-grasses; in the eastern portions of the plains where a more abundant rainfall obtains, bunch-grass often occurs on the fine-textured soils, crowding out the short-grasses.

Blackman (1905) points out that any one factor is operative so long as some other factor does not become limiting. Thus a favorable climate may support a given type of vegetation so long as the soil is good, but on impervious soils the great loss by run-off becomes a limiting factor and prevents the growth of that type of vegetation though the climate is still favorable. Therefore, any use of indicators must be made with the full understanding that the conditions indicated are the sum of all the factors of the habitat rather than any one singly. In order to determine any one it must first be determined as nearly as possible that the others are not limiting plant growth. An experienced observer can, by careful consideration, largely eliminate the edaphic factors. It is infrequent that such factors are so subtle that they cannot be found out by a comparison of several physiographically similar areas. Should the vegetation of one such area be more xeric than that of the others, and should there be no evidence that the rainfall here is less than that of the other areas, then it may be concluded that the soil of the one differing area is less permeable to water or in some other way causes the precipitation to be less effective. A difference thus attributed to edaphic factors may be disregarded in attempting to establish the climate.

This still leaves the factors of temperature, precipitation, evaporation, wind velocity and direction, etc. thoroughly mixed, and by means of plant indicators they can be only partially disentangled. The situation is made even more difficult by the fact that in most cases a "factor" is operative as a control of another factor. Thus wind and temperature are major controls of evaporation. Sheltered slopes bear a more luxuriant vegetation because wind and resultant evaporation are reduced in sheltered areas. The vegetation of waterways is heavier as a combined result of shelter and a concentration of soil moisture. Poleward facing slopes of mountains are often more heavily wooded than equatorward facing slopes because of the reduced insolation and evaporation as pointed out by Cottle (1932). With these principles in mind an

extensive examination of a region of rough topography will yield a satisfactory approximation of the climates of its component areas.

It must be understood, of course, that a set of rules formulated for one region is not directly applicable to all other regions. Thus, the occurrence of a species in the Sierra Madre may be indicative of a given condition, while the occurrence of the same species in the Rocky Mountains may indicate an entirely different condition. Furthermore, only a few species have so wide a geographic range. Therefore, the accompanying correlations are intended to apply only to the area in which they are described. There is, however, one set of rules which holds good much more generally. These relate to growth form. Areas of little or no summer verdure such as certain grasslands, thorny scrub, and stunted tree assemblages may be regarded as having relatively xeric conditions, usually with moderate or high temperatures. Dense forest, slender and crowded tree trunks, abundant herbaceous growth, and constant verdure throughout the growing season are indicative of mesic conditions. Finally, timberline and alpine meadows of stunted herbs at high altitudes are definitely correlated with low temperatures.

There follows an analysis of a northeast to southwest transect through the middle Sierra Madre Oriental in the state of Nuevo Leon, Mexico.

Method Employed

An area of relatively homogeneous relief with meteorological data available from a number of stations lends itself readily to accurate climatic classification. Where there is a corresponding homogeneity of vegetation, one may be fairly certain that the essentially similar data from the several stations truly indicate a widespread climatic type. The northeastern coastal plain in the Mexican states of Tamaulipas and Nuevo Leon is such an area.

With this known area as a starting point, it is the purpose of this paper to build a classification of climatic variants in the adjacent Sierra Madre Oriental on the basis of vegetational distribution. The coastal plain and low hills in the area are covered with a relatively homogeneous chaparral of mesquite *(Prosopis chilense)*, chaparro prieto *(Acacia amentacea)*, palo verde *(Parkinsonia aculeata)*, huisache *(Acacia Farnesiana)*, forestiera *(Forastiera angustifolia)*, cenizo *(Leucophyllum minus)*, hackberry *(Celtis pallida)*, vara dulce *(Lippia macrostachya)*, yucca *(Yucca australis)*, anacahuite *(Cordia Boissieri)*, and various cacti. Such areas are usually rather heavily grazed, but various short-grasses are fairly prominent among the shrubs. Gramas *(Bouteloua hirsuta, B. curtipendula)*, needle-grass *(Stipa mucronata)*, triodia *(Triodia texana, T. pilosa)*, and dropseed *(Sporobolus cryptandrus)* are the principal ones. (See Fig. 1.)

The village Montemorelos, at 432 m. (1400 ft.) altitude,[1] in Nuevo Leon is situated in such an area as this. The profile of the area under consideration (Pl. 1, Fig. A) passes through Montemorelos, where for a period of

1 The altitudes herein quoted were calculated from the topographic maps published by the Mexican Department of Agriculture. 1904, 1905.

nine years (1904 to 1913) a meteorological station was maintained. Nine other stations with varying lengths of record are located on the same plain. Data from these ten stations form the only basis for a quantitative classification such as that of Thornthwaite who designates the area as "mesothermal, semi-arid, and [with] deficiency of rainfall at all seasons". Jones (1932) in criticizing Thornthwaite's method points out the error of regarding any rainfall as "deficient at all seasons" in view of the fact that the native vegetation thrives under those conditions. It is true enough that the rainfall of the area under consideration is insufficient for the cultivation of most temperate field crops without the aid of irrigation. At Montemorelos a mean annual precipitation of 733 mm. (29 in.) has been determined. Page figures the so-called "tierra caliente" as extending well up the northeastern coastal plain into the Rio Grande Valley. Calvert (1908) includes the area in his zone of mean annual temperatures of 20° to 25° C. (68° to 77° F.) which agrees with Page after Hernandez (1923) and Sanchez (1925). The occasional cultivation of citrus fruits and reports from residents of frost averaging less than once annually further indicate rather high temperatures.

In view of the data used by Thornthwaite, Page, and Calvert and of the predominating desert vegetation, it seems reasonable to designate the area as *warm* and *arid* (the high temperatures and consequent high evaporation reduce the efficiency of the moderately low precipitation). This is to be used as a starting point, and all variations in humidity and temperature as indicated by the vegetation of adjacent areas are to be added to or subtracted from this primary designation.

Following the line of the profile (Pl. 1, Fig. A) southwest, the vegetation is seen to remain relatively constant until the foothills are reached (Fig. 2). A greater density of woody growth is the first indication of climatic change (at 750 m. or 2450 ft. altitude). Gradually, however, a change in composition occurs. Scrub oak and xeric tree species *(Quercus Canbyi, Q. fusiformis, Q. polymorpha,* and *Q. clivicola)* together with some of the characteristic shrubs of the plains zone occupy the rougher topograpy above 800 or 900 m. (2600 to 2925 ft.). Closer to the mountains these shrub zones take on a definitely highland character. Piñon *(Pinus edulis),* cedar *(Juniperus mexicana),* sumacs *(Rhus virens* and *R. pachyrhachis),* manzanita *(Arctostaphylos* spp.), maguey *(Agave* spp.), wild cherry *(Prunus Capuli),* and some oaks *(Quercus cordifolia, Q. flocculenta,* etc.) appear in addition to the previously mentioned oaks at 1000 to 2500 m. (3250 to 8125 ft.) altitude. Most of the plains species will have disappeared when the vegetation of the last named character has been reached (Fig. 7). Among the denser growths of shrubs the grasses are sparse, but there occur some areas (characterized by broad, flat expanses of fine soil) which are entirely grass covered. Grama grasses *(Bouteloua hirsuta* and *B. curtipendula),* buffalo grass *(Bulbilis dactyloides),* and a few others are present in varying degrees of abundance. This shrub zone is a broad one including many areas of essentially the same growth forms at both high and low altitudes, depending upon the exposure to prevailing winds as explained below.

That these areas differ in climate from the plains type is abundantly evidenced by the more luxuriant vegetation. Sensible temperatures here are definitely lower; the natives vouch for a more frequent occurrence of sub-freezing temperatures (from two to a dozen or more frosts annually), frozen precipitation, and cloudiness and rain than is found below. This type of area may be designated as *cool* and *semi-arid*. (Figs. 3, 4, 5, & 6).

When the shrubby oaks give way to more tree-like species *(Quercus chrysophylla, Q. Greggii, Q. affinis,* etc.) or themselves take on a more tree-like habit, a disappearance of the more xeric shrubs may be noted. Pines *(Pinus teocote* and *P. pseudostrobus),* hickory *(Carrya myristicaeformis),* and various shrubs such as maguey, madroño *(Arbutus xalapensis),* dogwood *(Garrya* spp.), etc. are added, and the vegetation may be termed a forest in the conventional sense of the word. Slender trunks, dense shade, and abundant growth of herbs and epiphytes (especially bromeliads) attest the true mesic nature of the area (Figs. 8 & 9). The frequency of heavy rains and long duration of cloudy periods are obvious even to a casual observer. Here the cultivation of corn, wheat, apples, plums and other small fruits, cucurbits, etc. is carried on without irrigation. This vegetation type lies between 1500 and 2800 m. (4875 to 9000 ft.) altitude. To the climate prevailing here may be applied the description *cool* and *sub-humid*.

The higher altitudes are covered with a truly subalpine forest of pine *(Pinus montezumae* and *P. ayacahuite)* and Douglas fir *(Pseudotsuga mucronata).* Here and there areas of aspen *(Populus tremuloides)* and, in the higher areas, a gooseberry *(Ribes rugosum)* occur, but the forest is remarkably simple in composition. (Figs. 10, 11, & 12). That this forest is the latitudinal equivalent of subalpine forests of farther north is judged by the occurrence of timberline and true alpine meadow immediately above such a forest on Cerro Potosí at about 3800 m. (12350 ft.) altitude. *Pinus montezumae* may not always be regarded as an indicator of subalpine conditions, for several varieties of the species occur at much lower, warmer, and drier altitudes. The variety on Cerro Potosí, however, is accompanied by other species already mentioned which are abundantly indicative of cold, moist situations. To such an area may be applied the description *cold* and *humid*.

An interesting feature of the subalpine area is the occurrence of meadows in its lower reaches (2800 m. or 9000 ft.). In the pine-oak forests of the *cool* and *sub-humid* areas, such meadows are cultivated. They consist usually of catchments of fine soil with a relatively high moisture content. In the subalpine area, however, the water content of the meadows is so great as to be disadvantageous. One such is found at La Jolla on the north slope of Cerro Potosí at an altitude of about 2800 m. (9000 ft.). In this community the natives find it better to cultivate adjacent drier slopes.

The high rate of evaporation caused by exposure to desiccating winds is responsible for the development of timberline and stunted tree growth on high peaks in this area. Precipitation apparently is just as high as in the adjacent *cold* and *humid* zone but is rendered ineffective by evaporation. On Cerro Potosí this area occupies the upper 100 to 200 m. (from 11700 to 12350 ft.

altitude). Poorly developed pines *(Pinus montezumae)* with a shrub layer of gooseberry, juniper *(Juniperus pachyphloea)*, and stone pine *(Pinus flexilis)* characterize the forest immediately below timberline. (Figs. 13 & 14). To the climate of this limited area may be applied the terms *cold* and *semi-arid*.

West of the Sierra Madre Oriental lies the extensive central plateau which is essentially desert in spite of its altitude (about 2000 m. or 6500 ft.). For purposes of simplification no distinction is now being made between the climate of this area and that of the eastern coastal plain. The more desert nature of the vegetation on the west agrees with the designation of this area by Page and by Van Cleef (1922) as relatively more extremely arid than the coastal plain. Calvert figures an area of lower mean annual temperature over the central plateau which is the result of more rapid loss of heat by radiation at higher altitudes and under almost cloudless skies. When this analytic method is applied areally, a study now in progress by the author, some basis of distinction will be employed. For the present the area may be designated as *warm* and *arid* with reservations concerning lower nocturnal temperatures and a generally lower relative humidity.

An interesting effect is illustrated (Pl. 1, Fig. B) in the rainshadow phenomenon. The air currents indicated in the figure are theoretical, but an examination of the distribution of the vegetation shows a general agreement between the designated courses of the winds and the distribution of highest humidity.

In the region of the middle Sierra Madre Oriental the rainbearing winds, prevailingly off the Gulf of Mexico, strike the mountains obliquely. Those which reach the west side of the mountains encounter the high temperatures of the west slopes, and precipitation ceases. The result is a minimum of precipitation beyond the *precipitation divide* with the climate almost as dry and little cooler than the adjacent desert. This seems simple, as it would be were it not for other complicating physiographic features. Each succeeding higher ridge is to a certain extent a precipitation divide until the highest is reached. More westerly lower mountain ranges are usually quite dry, but should they lie opposite a break in the eastern wall, some of the rain winds are allowed to pass the primary ranges and precipitate their moisture upon the lesser western ranges. Thus the precipitation divide is very irregular and cannot readily be located by means of a topographic map. It does not necessarily follow the top of the most salient range, and it is not infrequently supplemented by one or several minor divides along its eastern side. In general, however, the western half of the mountain area, as indicated by the vegetation (Figs. 15 & 16), is semi-arid while the eastern half is definitely moist.

A pronounced paradox is evident on the west slope of Cerro Potosí (Pl. 1, Fig. A). The relatively greater extent of humid forest and humid climate on the west slope would seem to contradict the theoretical action of the precipitation divide. However, an examination of the figured courses of the air currents reveals an explanatory condition. The prevailing winds strike the upper exposed eastern slope and rise over the peak. A wind of any intensity

may be expected to rise considerably beyond the peak as a result of its own momentum, thus producing precipitation on the west slope. Cerro Potosí is bounded on the west by the relatively broad plateau on which high daytime temperatures occur. The areas with these temperatures adjacent to the area of lower temperatures of the peak set up a strong convection which results in further precipitation on the west slope. It may be expected that the convection on the west will be much more intensive than that on the east by reason of the much broader area of high temperature immediately adjacent to the cool mountain as well as lower wind velocities in the lee of the mountain. That a large portion of the precipitation on Cerro Potosí comes in the form of convectional rains is evidenced by the nature of the storms. On a perfectly clear day a storm may be seen gathering about the crown of the mountain at midday or a little later. Such storms result in moderately heavy precipitation.

Summary

Five major climatic types have been distinguished in a cross section of the Sierra Madre Oriental in the state of Nuevo Leon (Pl. 1). These climates are characterized by distinct vegetational types and growth forms. There follows a brief description of each.

1. *Warm* and *arid*. This climate has been assigned to the eastern coastal plain, the low broad interior valleys, and the central plateau west of the mountains. On the coastal plain it is characterized by growths of thorny shrubs, principally mesquite, yucca, acacia, cacti, and the like (Figs. 1 & 2). In the western valleys and on the adjacent plateau and low slopes the shrubs are more stunted in form and consist mostly of creosote bush or gobernadora *(Larrea tridentata)*, lecheguilla *(Agave lecheguilla)*, cacti, and similar forms. On the east this zone reaches an altitude of about 750 m. (2500 ft.), but on the western edge of the mountains it reaches over 2000 m. (6500 ft.).

2. *Cool* and *semi-arid*. Areas of this nature lie about the skirts of the mountains generally above the *warm* and *arid* zone but definitely below the truly forested zones. They are characterized in this region by shrubs which include manzanita, sumac, piñon, maguey, and scrub oaks (Figs. 3, 4, 5, & 6). The most outstanding difference between this zone and the preceding one is the reduction in thorny species and the increase in broad-leafed evergreen forms. The height of growth in some cases may be less than that on the coastal plain, but the impression is one of greater density. This area is usually encountered between 1000 m. (3250 ft.) and 1550 m. (5000 ft.), but on south and west exposed slopes it may reach 2150 m. (7000 ft.) to 2500 m. (8125 ft.).

3. *Cool* and *sub-humid*. The lower forest areas coincide with the areas having this climatic type. They include forests of pine, pine and oak, pure oak, and oak and hickory (Figs. 8, 9, & 15). The areas are heavily wooded and, by the means of the slender crowded trunks of the trees, usually give a

definite impression of good moisture conditions. This area is encountered between 1500 and 2800 m. (4875 to 9000 ft.).

4. *Cold* and *humid*. On the higher peaks there occur areas which have a climate of this nature. Readily sensible low temperatures in summer and frequent precipitation have resulted in the development of a heavy subalpine forest between 2800 and 3600 m. (9000 to 11700 ft.) (Figs. 10, 11, & 12). *Pinus montezumae* is the principal tree. It is not, however, an infallible indicator. It should be regarded as subalpine only when accompanied by, or closely adjacent to, Douglas fir, aspen, and/or *Pinus ayacahuite*. Of course, any pure stand of *Pinus montezumae* at a *higher* altitude than an adjacent forest of *Pinus ayacahuite* and Douglas fir may safely be considered subalpine in character. Shrubs in this area are reduced to one species of gooseberry and an ocasional occurrence of other species.

5. *Cold* and *semi-arid*. Alpine meadows and stunted forests of pine with shrubs of gooseberry, juniper, and stone pine on the highest peaks (3600 to 3800 m. or 11700 to 12350 ft.) indicate a climate of this type. (Figs. 13 & 14).

At all times it must be kept in mind that protected ravines and poleward facing slopes, by reason of localization of soil moisture and reduced insolation, wind movement, and evaporation, will bear a more highly developed growth than general climatic distribution would suggest. Thus, the occurrence of Douglas fir in a cañon well within the *cool* and *sub-humid* zone of pine-oak forests is merely an indication of locally increased moisture and not of subalpine forest conditions. Similarly, the occurrence of trees in a ravine in the *warm* and *arid* shrub zone is of no climatic significance. Extensive poleward facing slopes and broad cañon floors, on the other hand, which bear more highly developed forests as a result of reduced insolation and evaporation may be regarded as having a different climate of sufficient extent to be mapped.

Conclusions

That the climate of an area may be evaluated in terms correlated with fitness for plant growth has been demonstrated. The value of this to ecologists and to geographers is two-fold: first, it allows workers to proceed in areas entirely without climatic records, and, second, it furnishes data in terms of fitness for life rather than in terms of isolated figures which may or may not mean something, depending upon whether or not the effect of a given factor is nullified by the limiting effect of another. Since the studies of ecology and geography, whether they be plant, animal, or economic, are concerned with the suitability of any given area to life, it seems desirable to express such fitness in terms of the life it produces.

Not less important is the unquestionable fact that no workers, no matter how experienced nor how well equipped with physical data, can express the fitness of a habitat for plant growth nearly so accurately as can the plant by its very growth in that habitat. The vegetation of a given area is a record not only of the present conditions but of the accumulated effects of climate over a period of many years which has constantly been active in selecting the

vegetation and in influencing the growth of the species which have persisted. Vegetation is a recording instrument such as no man-made device can ever equal.

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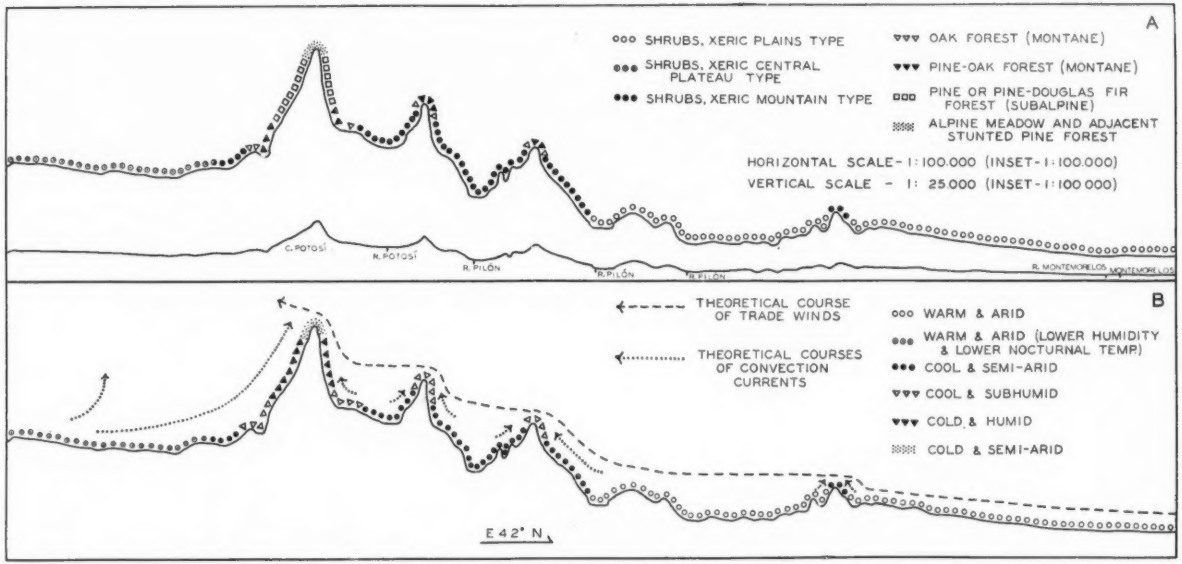


Fig. A.—A profile drawn across the Sierra Madre Oriental in central Nuevo Leon, Mexico. The vertical scale is exaggerated (x 4) to emphasize the relief. The inset is drawn to scale. The major vegetation types are plotted on the exaggerated profile. The direction is approximately at right angles to that of the mountain range and nearly coincides with the direction of prevailing (trade) winds.

Fig. B.—The same profile with the major climatic types plotted from the distribution of vegetation types. The figured courses of wind movements are theoretical. An attempt has been made to represent the intensity of convection currents by the relative lengths of the arrows indicating their directions.

LEGENDS FOR PHOTOGRAPHS

FIGURES

1. Chapparal of *Yucca* (Spanish dagger or palma), *Opuntia* (prickly pear), *Lippia*, *Condalia*, and *Acacia* on the coastal plain east of the mountains. The altitude is about 600 m. (1950 ft.).

2. *Acacia* and *Opuntia* (prickly pear) on the low foothills east of the mountains at about 750 m. (2450 ft.) altitude.

3. *Yucca* (Spanish dagger), *Nolina* (beargrass), *Pinus edulis* (piñon), *Quercus cordifolia* (scrub oak), etc. in the xeric mountain shrub zone. The altitude is about 2000 m. (6500 ft.), in an interior valley.

4. *Quercus clivicola* (oak), *Agave* (maguey), *Quercus cordifolia* (scrub oak), etc. in the transition between xeric mountain shrubs and the forest zone. The altitude is about 2200 m. (7150 ft.), in an interior valley.

5. Xeric shrubs of the low mountain type, at 1300 m. (4225 ft.) altitude, characteristic of the lower western slopes and dry interior valleys. *Acacia*, *Nolina* (beargrass), and *Rhus virens* (evergreen sumac) are the principal species.

6. Xeric shrubs of the high mountain type, at 2500 m. (8125 ft.) altitude, on the upper west facing slopes of those mountains to the west of the divide. *Quercus cordifolia* (scrub oak), *Rhus virens* (evergreen sumac), and *Yucca* (Spanish dagger) are the important plants.

7. Low forest of *Quercus clivicola* (oak) with *Agave* (maguey) at about 1300 m. (4225 ft.) altitude on the east slope. This type lies below the mesic forest of pine (Fig. 8) and above the xeric shrub zones (Fig. 2).

8. A mesic forest of *Pinus teocote* (pine) and *Quercus affinis* (oak) at about 1500 m. (4875 ft.) altitude on the east slope. Note the slender tree trunks.

9. Mesic forest of *Pinus teocote*, *P. pseudostrobus* (pines), *Pseudotsuga mucronata* (Douglas fir), *Quercus affinis* (oak), etc. at about 2200 m. (7150 ft.) altitude on the east slope.

10. Lower subalpine forest of *Pinus montezumae* (pine) at about 3000 m. (9750 ft.) altitude on Cerro Potosí. The shrubs are *Quercus errans* (scrub oak), and the herbs are principally *Pentstemon* (beard-tongue).

11. Subalpine forest of *Pinus montezumae* (pine) at 3500 m. (11375 ft.) altitude on Cerro Potosí. The herbs are chiefly lupines.

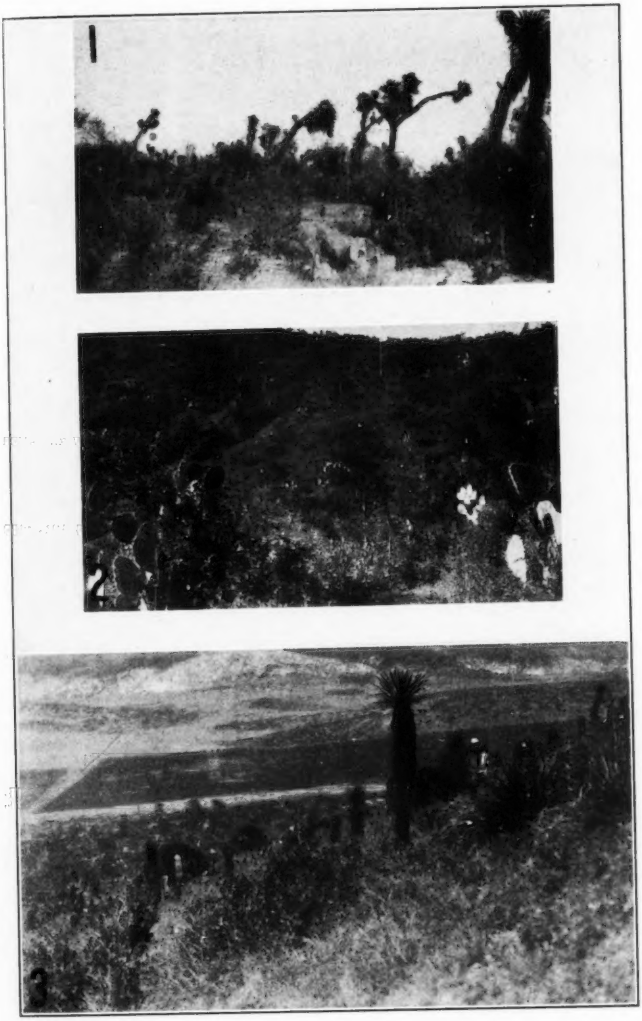
12. Subalpine forest of *Pinus montezumae* (pine) at 3600 m. (11700 ft.) altitude on Cerro Potosí. The herbs are much larger and denser and of a greater variety than those above timberline seen in the next two figures.

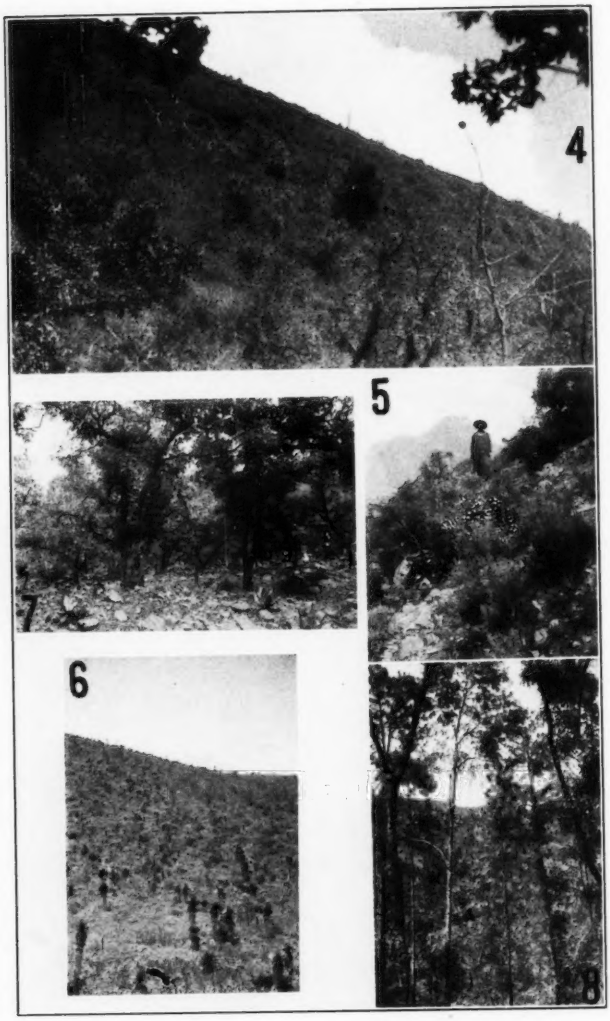
13. Timberline of *Pinus montezumae* (pine) at 3700 m. (12025 ft.) on Cerro Potosí. The shrub in the foreground is *Pinus flexilis* (stone pine).

14. The alpine meadow at 3800 m. (12350 ft.) on Cerro Potosí. *Lupinus potosina* (lupine) and a few low herbs comprise the entire vegetation.

15. Forest of *Pinus teocote* and *P. pseudostrobus* (pines) on a northeast (windward) facing slope. The altitude of the divide is 2300 m. (7475 ft.).

16. The same mountain as in Fig. 15 showing the southwest (leeward) exposed slope. The xeric forest in the foreground is composed of *Quercus clivicola* and *Q. porphyrogenita* (oaks).

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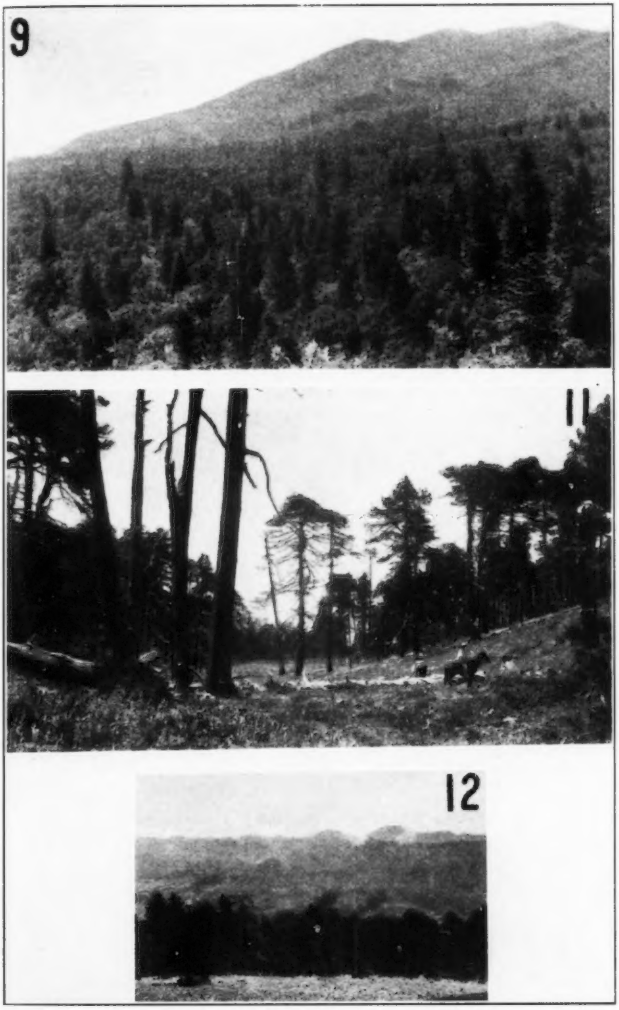
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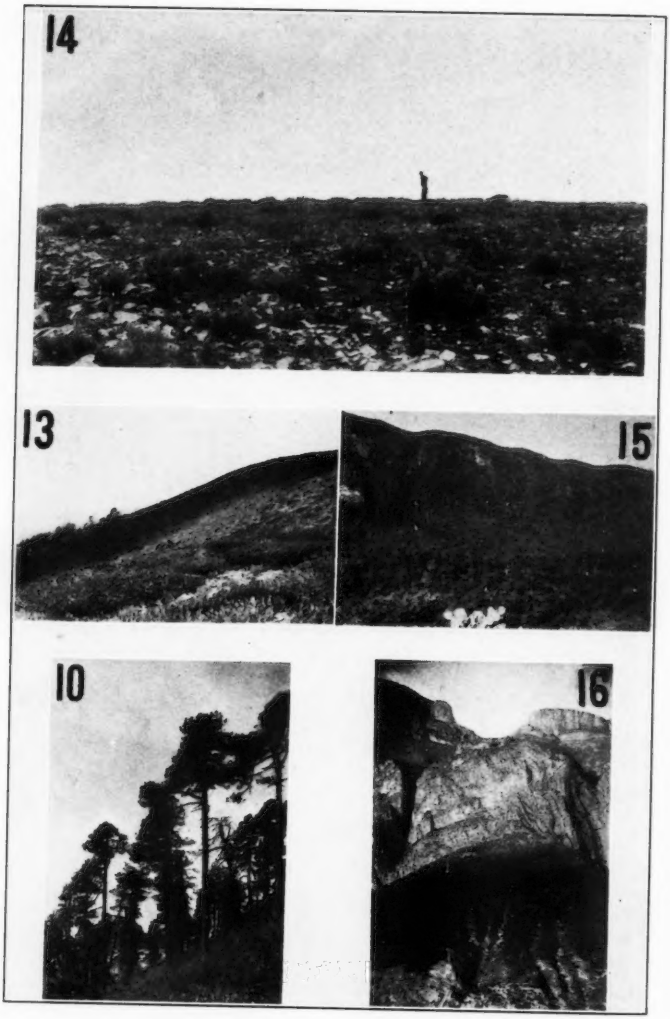
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Vegetative Reproduction in Conifers

J. E. Potzger

Vegetative or monogenetic reproduction is not so common in conifers as in woody angiosperms, especially in more favorable habitat sites, yet it occurs even under forest conditions in more species of evergreens than is usually recognized. Apparently it is stimulated by rigorous habitat conditions such as low temperature of arctic and alpine climates, sand dunes and rocky shallow soils. This type of propagation is a decided aid in ecesis and dominance in a habitat, for it removes multiplication of numbers from the hazards of seedling establishment and development, making the offspring immediately a vital element in the competition for light and moisture with herbaceous plants.

The most prolific vegetative reproduction in conifers which has ever come to the attention of the writer occurs in *Thuja occidentalis* L. on the limestone cliffs and shallow-soiled uplands of Mackinac Island, Michigan. Clumping of trees due to layered branches is the rule rather than the exception in these forests. While the trees are young, the lower branches droop down and gradually the region of contact becomes covered with soil and humus, adventitious roots develop on the ventral surface of these branches (Fig. 1) and

Fig. 1. Root development on layered branch of Thuja.

they then assume the upright position of stems, eventually developing into trees. Each parent tree, thus, becomes the center of a "colony" of trunks which even at maturity retain at the base the geniculate curve of the former drooping branches (Fig. 2).

This layering habit gives Thuja a unique ecological advantage over other species in the area, so that extensive forests are dominated by pure stands of

arbor vitae. Layering is very common on dry slopes and uplands but was never observed in bogs and wet lowlands.

The ability to reproduce vegetatively is not limited to a few species but according to reports in the literature it may occur in most genera of conifers in the northern hemisphere.

Cooper (1911) describes layering in *Abies balsamea* (L.) Mill. and lists thirteen titles dealing with reports and descriptions of vegetative reproduction in conifers. In 1931 the same author adds *Tsuga heterophylla* (Raf.) Sang.; *Tsuga mertensiana* (Bong.) Sarg., and *Picea sitchensis* (Bong.) Carr to the list of species reported previously.

Fuller (1910) observed layering in *Picea mariana* (Mill.) BSP. on xerophytic granite hills along the Sanguenay River, Quebec. Harvey (1927) says

Fig. 2. Colony of mature Thuja stems developed from layered branches. Mackinac Island, Michigan

that in the dunes on Cape Breton Island both *Picea canadensis* (Mill.) BSP. and *Abies balsamea* (L.) Mill. reproduce abundantly by layering, "Giving a long-lived and self-perpetuating stand."

From Europe, Lemberg (1933) reports it for *Pinus sylvestris* L. and *Picea abies* (L.) Karst. in the dunes on the north shore of Lavansaari, while Ehrström observed it in the latter species on the dunes of Kuokkala. Other reports are the one from Muenster (1927) for *Picea excelsa* Link and from Berg (1930) of Ostrask, Sweden, for *Abies sibirica* Ledeb.

However, monogenetic reproduction is not limited to layering only. In a few conifers, chief among them *Sequoia sempervirens* (Lamb.) Endl. it may be by stool shoots. According to Lamb (1899), *Pinus echinata* Mill., *Tumion californicum* (Torr.) Greene, and *Pseudotsuga douglasi* Carr. reproduce by root suckers. Metcalf (1925) says, "it (Tumion) sprouts vigorously from the stump as does redwood."

Phillips (1911) reports coppicing in two conifers of the Southwest, viz. *Juniperus pachyphloea* Torr. and *Pinus chihuahuana* Engelm. Both of these species develop root and stump sprouts. The latter species most commonly produces the sprouts from the root collar or thirty centimeters above the ground, while the former produces them at considerable distance from the ground. This author also lists *Pinus echinata* Mill and *Pinus rigida* Mill. as species where reproduction from the root sprouts is of importance in reforestation.

From the Handbook of Coniferae by Dallimore and Jackson (1923) we quote the following: "Cuttings of various species, particularly Cupressus may be rooted. A few species (notably *Cryptomeria japonica* Don. and *Sequoia sempervirens* (Lamb.) Endl.) produce coppice shoots from cut-over trees."

In conclusion we present in summary the species of conifers for which vegetative reproduction has ben reported:

Abies balsamea (L.) Mill.
Abies lasiocarpa (Hook) Nuttall
Abies sibirica Ledeb.
Cryptomeria japonica Don.
Cupressus sp?
Juniperus pachyphloea Torr.
Picea abies (L.) Karst.
Picea canadensis (Mill.) BSP.
Picea excelsa Link.
Picea mariana (Mill.) BSP.
Picea sitchensis (Bong.) Carr.
Pinus chihuahuana Engelm.
Pinus echinata Mill.
Pinus montana Mill.
Pinus rigida Mill.
Pinus sylvestris L.
Pseudotsuga douglasi Carr.
Sequoia sempervirens (Lamb.) Endl.
Thuja occidentalis L.
Tsuga heterophylla (Raf.) Sarg.
Tsuga mertensiana (Bong.) Sarg.
Tumion californicum (Torr.) Greene.

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Some Blood Parasites from Nebraska Birds*

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The following observations on the protozoan genera *Haemoproteus, Leucocytozoon, Plasmodium,* and *Trypanosoma,* with notes on the immature nematode group *Microfilaria,* are based for the most part on material collected at Peru, Nebraska, during the spring and summer of 1935 and 1936. Eighty-nine different birds were examined representing nineteen families and forty-four species. Of this group twenty-six were found to harbor one or more genera of blood parasites.

The vernacular and scientific names of the birds are according to the fourth edition of the American Ornithologists' Union Checklist (1931), except that no special cognizance is taken of sub-species, for such determinations are considered of little value in studies of this type.

Smears were made from the superficial vein of the wing or leg, but in a few cases the blood was taken directly from the heart. The smears were stained with Wright's, unless otherwise stated, and carefully examined for at least twenty minutes under oil before being declared negative. Specimens were drawn with the aid of a camera lucida and then measured by means of dividers.

In dealing with this material the authors have been hard pressed at times in deciding as to the specific status of some forms. Part of this dilemma is due to the fact that many described species are hard to identify, because of the absence of good descriptions and illustrations plus the fact that specific differences are sometimes hard to define. As a consequence of these difficulties the authors have decided to follow a conservative policy in naming new species. In some cases variety names have ben proposed where the hosts were widely separated systematically or where the morphological differences were hardly of such magnitude as to clearly justify the creating of a new species. Such a procedure is in line with the policy suggested by Stiles (1927) who, in discussing this point, said, "My viewpoint is that in case of reasonable doubt as to the systematic status of an animal it is always wise to publish it under a new name."

The authors are indebted to Mr. W. E. Beed, of the Bureau of Biological Survey, for submitting blood smears of certain birds from the vicinity of Valentine, Nebraska, and to Drs. George E. Hudson and H. W. Manter, of

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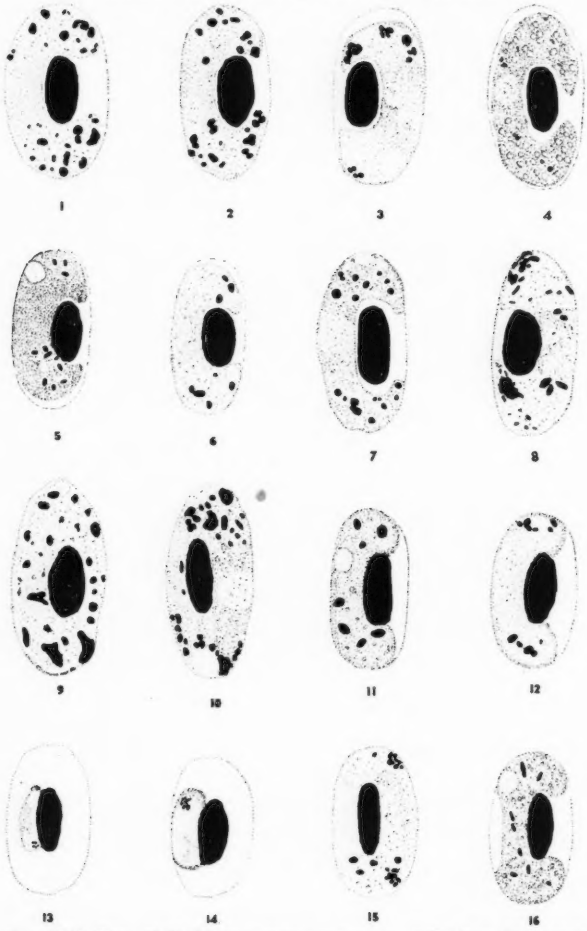

Plate 1. x 1942. Figs. (1-2) *Haemoproteus noctuae* var. *cellii* from the Screech Owl. A micro- and macrogametocyte respectively. (3-4). *Haemoproteus noctuae* var. *nebraskensis* from the Great Horned Owl. A micro- and macrogametocyte respectively. (5-6) *Haemoproteus hedymelis* from the Red-breasted Grosbeak. A macro- and microgametocyte. (7-10) *Haemoproteus velans* from the Northern Flicker. Figs. 7 and 8 show a macro- and microgametocyte before they have completely enclosed the host cell nucleus. In figures 9 and 10 the male and female parasites have entirely enclosed the nucleus of the host cell. (11-12) *Haemoproteus prognei* from the Purple Martin. A macro- and microgametocyte. (13-16) *Haemoproteus picae* from the Magpie. Fig. 13 shows a young gametocyte lying close to the host cell nucleus. Fig. 14 an older gametocyte. Figs. 15 and 16 show adult male and female gametocytes.

the University of Nebraska for smears of certain birds taken in the vicinity of Lincoln.

Haemoproteus Kruse, 1890

Haemoproteus noctuae var. cellii var. nov.

Pl. 1, Figs. 1-2

Four species of Haemoproteus have been described from owls and there are many host records from different parts of the world (See Coatney, 1936). Celli and San Felice (1891) described three species: *H. aluci* from *Syrnium aluco*, *H. bubonis* from *Strix flammea*, and *H. noctuae* variety A and variety C from *Athene noctuae*. Mayer (1911) described *H. syrnii* from *Syrnium aluco*. The description of *H. aluci* and *H. bubonis* are meager and decidedly confusing. The figures of these forms lend little help toward their identification. *H. noctuae* variety A is well described and is the true halteridium parasite of the owl; and the variety C, as recently pointed out by Wolfson (1936) is a Plasmodium, which, if a distinct species, is *P. subpraecox*. *H. syrnii* is essentially like *noctuae* except for the fact that Mayer described some basophilic granules in specimens which were heavily stained.

Halteridium parasites have been found in one Screech Owl *(Otus asio)*. The adult female gametocytes measured 13.78μ to 22.44μ in length and from 2.24μ to 3.53μ in width. The mean size was 17.96μ by 2.89μ. The ends of the parasites were pointed rather than rounded. The parasites were generally in close contact with the host cell membrane but they did not contact the nucleus of the host cell. The cytoplasm stained a dark blue and had a few indistinct vacuoles. The pigment granules varied in number from 19 to 26 with an average number of 22.5. The nucleus stained a dark pink, was irregularly oval and was found toward the periphery of the host cell. The nucleus measured 1.92μ to 3.85μ in length and from 0.80μ to 2.24μ in width with a mean size of 3.11μ by 1.57μ. Many host cells had the nucleus displaced. Linear hypertrophy of the host cell was evident.

The male gametocytes measured 11.54μ to 20.82μ in length by 2.24μ to 3.21μ in width with a mean size of 15.56μ to 2.79μ. The parasites were close to the periphery of the host cell, except at the ends, but they did not contact the nucleus of the host cell. The granules were large, rod-like to irregular, and numbered from 8 to 24 with a mean of 17. In the younger forms the nucleus was distinct and stained a dark pink. In the older forms this body stained a light pink and was indistinct, sub-rectangular in outline and measured 3.85μ to 7.69μ in length and 2.20μ to 3.15μ in width. The mean size was 6.18μ by 2.74μ. Linear hypertrophy of the host cell was evident and about half had the nucleus displaced.

The halteridia from the screech owl resemble *H. noctuae* but differ from this form in that the growth stages all had smooth contours and the nuclei of the macrogametocytes were located near the periphery of the parasite next to the host cell membrane. The screech owl halteridium also had a greater number of granules than *H. noctuae*.

Haemoproteus noctuae var. **nebraskensis** var. nov.

Pl. 1, Figs. 3-4

The Haemoproteus reported here was found in the blood of a Great Horned Owl *(Bubo virginianus)*. The bird also harbored Leucocytozoa and, during the twelve days this owl was under observation, one trypanosome was seen.

The full grown female gametocytes measured from 17.48μ to 24.84μ in total length and from 2.76μ to 4.14μ in width. The mean size was 20.18μ by 3.05μ. The parasites had rather pointed ends and, in many cases, they almost completely enclosed the host cell nucleus. They were found not in close contact with the host cell membrane or its nucleus. A clear zone was particularly evident around the nucleus of the host cell. The cytoplasm stained a purplish-blue and showed many small indistinct vacuoles. The pigment granules were round to oval and numbered from 17 to 29 with a mean of 20. The nucleus was roughly spherical and stained a light red. This structure measured from 1.84μ to 3.68μ in length and from 1.38μ to 3.20μ in width with a mean size of 2.64μ to 2.28μ.

The adult male gametocytes measured 16.56μ to 22.08μ in length and from 1.84μ to 3.68μ in width with a mean size of 18.54μ by 2.93μ. The parasites had rather pointed ends and, as with the macrogametocytes, many of them almost enclosed the host cell nucleus. These parasites did not touch the host cell nucleus. They contacted the periphery of the host cell only along the side while at the ends, or poles of the cell, they pulled away leaving a clear area. The cytoplasm and nucleus of these parasites stained a dark pink, the latter structure was so diffuse that its boundaries could not be made out with certainty. The granules were rounded to oval and in many cases were clustered together at the ends of the parasites. Where counts of the individual granules could be made the number ran from 12 to 21 with a mean of 15.5. Nuclear displacement was seen in about half of the cells harboring adult parasites of both sexes. There was no host cell hypertrophy.

The known species of halteridia from owls were discussed above under *H. noctuae* var. *cellii* and will, therefore, not be repeated here. The parasites from the great horned owl are very similar to *H. noctuae* but differ in that the adult gametocytes do not commonly enclose the host cell nucleus. This form was larger than the variety *cellii* and they do not ordinarily contact the host cell membrane.

Haemoproteus hedymelis sp. nov.

Pl. 1, Figs. 5-6

There are some thirty-eight genera of the family Fringillidae found in North America and Haemoproteus parasites have been reported, by American investigators, from only the sub-family Emberizinae. Opie (1898) reported these parasites from *Melospiza* and Novy and MacNeal (1905) found them in *Melospiza* and *Spizella*. Manwell and Herman (1935) have found halteridia in *Passerculus, Junco, Spizella,* and *Melospiza*.

Two species have been named from members of the family Fringillidae. *H. fringillae* Labbé, 1894 was described from the chaffinch, *Fringilla coelebs* a member of the sub-family Fringillinae and *H. mazzai* was named by Parodi and Niño, 1927 from *Pheucticus aureiventris*. According to Labbé, *H. fringillae* had a tendency to surround the nucleus of the blood corpuscle. The forms were elongate and thin and often had indentations along their edges. No measurements were given. The specific diagnosis of *H. mazzai* is based on the decided displacement of the host cell nucleus and the tendency of this parasite to burst out of the host cell; frequently the host cell nucleus remains attached to the emerged gametocyte. The parasites had rounded ends and measured 12μ long by 3.5μ wide.

The halteridia reported here were found in three Red-breasted Grosbeaks *(Hedymeles ludovicianus)*, sub-family Richmondena, out of four examined. There are four other records from this sub-family, all from England. The full grown female gametocytes measured from 10.90μ to 14.42μ in length and from 1.92μ to 4.49μ in width with a mean size of 12.53μ by 2.98μ. The parasites generally had smooth rounded ends, this region being a little broader than the nuclear region. More than half were in close contact with the host cell nucleus while the number of those making contact with the periphery of the host cell was about equally divided. The cytoplasm stained light blue and had indistinct and diffuse vacuoles. The granules were elliptical to rod-shaped and numbered from 8 to 12 with a mean of 9.2. The nucleus stained pink, was almost circular and lay decidedly toward one end, off center, away from the host cell nucleus. The host cell nucleus was displaced laterally but host cell hypertrophy was absent. The nucleus measured 1.60μ to 2.56μ in length and from 1.60μ to 2.56μ in width with a mean size of 2.04μ by 1.79μ.

The adult male parasites were scarce in the blood of all birds postive for this infection. These forms measured 9.63μ to 11.22μ in length and from 1.92μ to 3.21μ in width with a mean size of 10.10μ by 2.89μ. The ends of the parasites were rounded. As with the macrogametocytes, many of these forms were in close contact with the host cell nucleus while only a few made close contact with the periphery of the host cell. Vacuoles were present but were indistinct and diffuse. The granules were elliptical to rod-shaped and numbered from 7 to 10 with a mean of 7.75. The nucleus stained a light pink and measured 4.49μ to 6.09μ in length and from 1.92μ to 3.21μ in width with a mean size of 5.5μ by 2.89μ. The nucleus of the host cell was displaced in about half the examples and host cell hypertrophy was lacking.

Haemoproteus velans sp. nov.

Pl. 1, Figs. 7-10

The halteridia reported here were found in one Northern Flicker *(Colaptes auratus luteus)* out of four examined. There seems to be no other record of an Haemoproteus from a North American representative of the family Picidae although at least four genera of woodpeckers have been examined.

The adult gametocytes measured from 20.18μ to 28.20μ in total length and from 1.92μ to 3.21μ in width. The mean size was 24.46μ by 2.65μ.

During growth these forms gradually surrounded the nucleus displacing it toward the periphery of the cell opposite the parasite nucleus. The young adults stained a deep blue and had many indistinct and diffuse vacuoles. The full grown macrogametocytes also stained a deep blue and generally had large vacuoles, located at the poles of the host cell. The pigment granules were, in many cases, clustered together and therefore difficult to count. Where counts could be made the average number of these granules was 31. The nucleus was oval to nearly round and stained pink. The mean size of the nucleus was 2.77μ by 1.89μ. Host cell hypertrophy was evident, especially in the linear dimensions.

The adult microgametocytes measured 22.44μ to 27.88μ in total length and from 1.92μ to 3.20μ in width. The mean size of these parasites was 24.76μ by 2.83μ. The adult forms, like the macrogametocytes, completely filled the host cell. Large vacuoles were present and were generally located at, or near, the poles of the host cell. The pigment granules had an average number of 21. These granules, instead of being localized at the ends of the parasite, as is typical of the microgametocytes of this genus, were scattered throughout the cytoplasm even invading the nuclear region. The larger and darker staining granules were generally found near the poles. The younger male gametocytes had the nuclear region free of these granules. The nucleus was elongate-ovate to sub-rectangular and was opposite the host cell nucleus. The host cell nucleus was displaced laterally and linear hypertrophy was evident.

According to the available literature three species of Haemoproteus with gametocytes that entirely surround the host cell nucleus have been described. These species are: *H. danilewskii* Kruse, 1890, *H. fringillae* Labbé, 1894 and *H. maccallumi* Novy and MacNeal, 1904. The first two species do not fill the host cell as is true for *H. velans;* while *H. maccallumi,* contrary to the original discription, is of the *H. columbae*-type which does not enclose the nuclear body. In addition to the named species Clarke (1936) reported an Haemoproteus of this type from the ruffed grouse, *Banasa umbellus,* before the Royal Society of Canada. This investigator has kindly supplied the present authors with a detailed description of this parasite and photomicrographs of the organisms. The grouse Haemoproteus seems to differ from *H. velans* mainly in that there is no displacement of the host cell nucleus and no enlargement of the host cell. It is possible, however, that the grouse parasite may belong to this species. It is of interest to note, also, that Huff (1937) has found in the blue jay, an Haemoproteus which he considers identical with the form from the flicker described above.

Haemoproteus prognei sp. nov.

Pl. 1, Figs. 11-12

Galli-Valerio (1902) recorded an Haemoproteus from *Hirundo rustica* which seems to be the first record of this genus of blood parasites from any member of the family Hirundinidae. The Sergents (1905) examined eleven swallows of *Hirundo* sp., in one of which they found an Haemoproteus which they considered to be *H. danilewskii.* Another swallow carried a different

organism which they named *H. danilewski* var. *hirundinis*. Their description of this variety was brief, without measurements, and accompanied by one figure, that of a female gametocyte. Balfour (1908) recorded an Haemoproteus from *Hirundo aethiopia*.

In 1922 Franchini described *H. chelidonis* from *Chelidon urbica* Linné. This halteridium had been found by Franchini in six birds out of twenty examined. Along with the typical characteristics of the genus Franchini gave the diagnostic characteristics of the new species. The female gametocytes had the nucleus placed near one end and the pigment was in fine granules. The male forms, on the contrary, had a large centrally located nucleus and the granules clustered in small masses at the ends. He gave the measurements as 6-9μ long by 1-2μ wide. In the same paper Franchini mentioned that Butler found halteridium parasites in *Hirundo aetiopica* but gave no reference to a paper by this investigator.

In 1923 Franchini published another paper in which he recorded the results of his examination of fifty more *C. urbica* and the same number of *H. rustica*. In fifteen of the former species he found *H. chelidonis* and four of the latter harbored another Haemoproteus (the table shows only two postive for this genus) which he described but did not name. The adults of this form displaced the host cell nucleus and the females were larger than the males.

In the course of this survey one adult and five young Purple Martins *(Progne subius)* were examined. Only the adult bird carried halteridia. The adult female parasites measured 11.54μ to 15.38μ in length and from 1.92μ to 3.21μ in width. The mean size was found to be 13.36μ by 2.52μ. These gametocytes had rounded ends and stained a light blue. The vacuoles were indistinct. The periphery of the adult parasites was in contact with the cell membrane and the nucleus of the host cell in most of the parasites studied. In many examples the association between the host cell nucleus and the parasite was so close that the nucleus semed to lie in a groove in the parasite. The pigment granules were decidedly refractile, elliptical to rod-shaped and numbered from 7 to 13 with a mean of 9.4. The nucleus measured 1.85μ by 1.69μ and stained pink. In more than half of the parasites this body was located toward one end close to the host cell nucleus. The nucleus of the host cell showed lateral displacement. Linear hypertrophy was evident in a majority of the parasitized cells.

The male gametocytes measured 9μ to 15.38μ in total length and 2.24μ to 3.53μ in width with a mean size of 12.49μ by 2.78μ. The ends of the parasites were rounded, stained a pale blue and had indistinct vacuoles. The parasites made close contact with the host cell periphery and its nucleus. The granules were refractile, elliptical to rod-shaped, and numbered from 5 to 20 with a mean of 10.2. The nucleus stained a light pink and was located opposite the host cell nucleus. In width the nucleus seemed to fill the whole of the parasite measuring from 2.24μ to 3.53μ in length and from 2.21μ to 4.49μ in width. The mean size was 2.78μ by 3.88μ. The host cell nucleus was displaced laterally and no host cell hypertrophy was evident.

The halteridium parasites of the purple martin do not fit the descriptions of any of the designated species. However, they do compare more favorably with the Sergent's variety *hirundinis* than with any other. They differ from this variety in their close affinity for the host cell nucleus, their tendency to curve around the nucleus, and in the position of the nucleus of the female gametocytes.

Haemoproteus picae sp. nov.

Pl. 1, Figs. 13-16

A Magpie *(Pica pica hudsonia)* was taken late in the fall of 1936 and when brought to the laboratory was found harboring Plasmodia and Leucocytozoa, to be described later. The bird was under observation in the laboratory during the winter and on April 26, 1937 numerous Haemoproteus parasites in all stages of growth were found in the blood. This was undoubtedly a relapse infection for the host had been kept in a screened cage. The provocative which brought this latent case into relapse is not known. The daily course of the infection was studied for a period of two weeks and then smears were made at three to four day intervals for approximately a month. The infection followed a typical course as described by the senior author (1933) for *H. columbae* of the pigeon's blood. A microfilaria was found while studying the halteridium infection.

Danilewsky (1888) seems to have been the first to find halteridia in the blood of a magpie. The only other record seems to be that of Galli-Valerio (1902) who records this genus from *Pica caudata*. There are numerous other records of halteridia from members of the family Corvidae (See Coatney, 1936) but only one has been given a specific name. Kruse (1890) described *H. danilewskii* from the hooded crow, *Corvus cornix*. According to Kruse's lucid description the species exhibits the typical growth stages and the adult gametocytes entirely surround the nucleus. Affinity for the nucleus of the host cell is evidently lacking for no mention is made of it and only one (Fig. 8) of his well executed drawings shows a parasite making contact with this body.

The young gametocytes were found anywhere in the host cell. As growth continued the parasites took up a position parallel to the host cell nucleus and by the time they had reached a length of 7.5μ most of them were lying in contact with the nuclear body. This close affinity between the parasite and the host cell nucleus was maintained during subsequent development. The young-adult microgametocytes generally had 4 to 8 pigment granules grouped at one end of the parasite. The nucleus of these forms was large.

The adult macrogametocytes measured 12.82μ to 16.02μ in length and from 1.60μ to 3.55μ in width. The mean size was 14.49μ to 2.13μ. The middle region of the parasites differed from the ordinary columbae-type in that there was a decided depression in the parasite body next to the periphery of the host cell. (Pl. 1, Fig. 16) The ends of the parasites were rounded. In general, the gametocytes were in contact with the host cell nucleus and with the periphery of the host cell except in the region of the depression. The

cytoplasm stained dark blue, with Giemsa, and had indistinct vacuoles. The pigment granules were rod-shaped to elliptical and varied in number from 8 to 15 with an average number of 10.1. The circular nucleus stained red and was located toward one end next the periphery of the host cell. This body measured 1.92μ to 3.20μ in length and 1.60μ to 2.56μ in width. The mean size was 2.32μ to 1.90μ. The host cell nucleus was generally displaced laterally. Linear hypertrophy of the host cell was evident.

The adult microgametocytes had rounded ends and measured 11.86μ to 15.80μ in length and from 1.60μ to 4.17μ in width, the mean size was 13.44μ by 2.83μ. The parasites contacted the membrane and the nucleus of the host cell throughout their entire length. The cytoplasm took very little stain and the nucleus stained a pale pink with Giemsa. The nucleus filled the entire cell in width and measured from 4.81μ to 9.28μ in length with a mean of 6.89μ. There was some hypertrophy of the host cell and the host cell nucleus was displaced laterally.

Haemoproteus picae differs from all other named froms in having a decided depression in the outer boundary of the macrogametocytes. It differs from *H. danilewskii*, the only other named species from a member of the family Corvidae, in that the gametocytes do not enclose the host cell nucleus and in the decided affinity shown for this body.

Haemoproteus maccallumi Novy and MacNeal

Novy and MacNeal (1904) described *H. maccallumi* from the mourning dove, *Zenaidura macroura carolinensis*. The description was brief and not accompanied by figures. These authors published the same description a year later. The diagnostic characteristics of the species were, "Grows on one side, or may completely surround the nucleus. The fully developed sexual forms fill and somewhat distend the blood cells." The species was next reported from the same host by Huff (1932). This author called attention to the absence of any constant difference in morphology between *H. maccallumi* and *H. columbae* of the pigeon's blood, and raised the question as to whether the two species are distinct since he was able to transmit *H. maccallumi* to the pigeon by the Hippoboscid fly, *Pseudolynchia maura* Bigot.

H. maccallumi reported here was found in the blood of two mourning doves examined during the course of this survey. Upon comparison of the adult gametocytes with the same forms of *H. columbae* it was seen as pointed out earlier by Huff, that there were no constant morphological characters that could be used to separate the two species. However, it is proposed to treat them as distinct species in view of the fact that the senior author (1933) was unable to transmit *H. columbae* to the dove either by allowing infected flies, *P. maura*, to feed upon them or by injecting a saline suspension of the comminuted insects. As a distinct species, then, the description of *H. maccallumi* must be amended to read like that for *H. columbae* Kruse, because the adult forms of *H. maccallumi* do not completely surround the nucleus. nor do they, as a rule, fill and distend the host cell.

Haemoproteus sacharovi Novy and MacNeal
Pl. 2, Figs. 1-2

H. sacharovi was found associated with an infection of *H. maccallumi* in the two doves mentioned above. This species was named by Novy and MacNeal (1904) from the mourning dove, *Zenaidura macroura carolinensis*. Their description was clear but brief. These same authors again reported this species in 1905 and 1905a. Huff (1932) recorded the same species from the dove. This investigator amplified Novy and MacNeal's original description and figured the gametocytes for the first time.

Gametocytes of this species, as described and figured by Huff, have been found. In addition, a type of adult gametocyte which completely encloses the host cell nucleus was present. (Pl. 2, Fig. 1-2). In smears from one bird more than fifty per cent of the full grown parasites were of this type. Only the gametocytes of this type will be discussed here.

The female gametocytes were generally in contact with the host cell membrane but they seldom made contact with the nucleus of the host cell. The cytoplasm of the parasite stained blue. The nucleus was round and stained red. This body seemed to have no definite location, being found either at one end or near the middle of the parasite. In almost all cases a distinct karyosome, blepharoplast of Novy and MacNeal, was present. There were numerous indistinct vacuoles. As many as twelve dark-staining granules were found in one parasite but the number was generally less than five. Total host cell hypertrophy was the rule.

Only a few male gametocytes of this type were seen. With these forms the parasite was lying free in the cytoplasm of the host cell leaving a clear non-staining zone around the nucleus and between the parasite and the periphery of the host cell. The nucleus was diffuse and stained a light pink. The cytoplasm stained a light blue. The granules were few and very small. The size of the host cell was increased in all dimensions.

Leucocytozoon (Leucocytozaire) Danilewsky, 1890

During the investigations on the genus *Leucocytozoon* a probable case of synonymy has come to the authors' attention. Wickware (1915) described *Leucocytozoon anatis* from ducks in Ontario, Canada and indicated that he knew of no previous description of a similar parasite of ducks. O'Roke (1934) noted the fact that Mathis and Leger (1911) found a leucocytozoon in a teal duck in Tonkin, China, which they figured but neither described nor named. Wenyon (1926) in his host list of blood protozoa records a species, *Leucocytozoon simondi* Mathis and Leger (1910) described from a teal duck *Nettion crecca* (=*Querquedula crecca*) and Coatney (1937) in his catalog of the genus *Leucocytozoon* records the same data. The reference given by Wenyon and Coatney is correct and Mathis and Leger (1910) did describe *L. simondi* from the duck, *Querquedula crecca*.

Most of the workers concerned with the leucocytozoa of ducks have failed

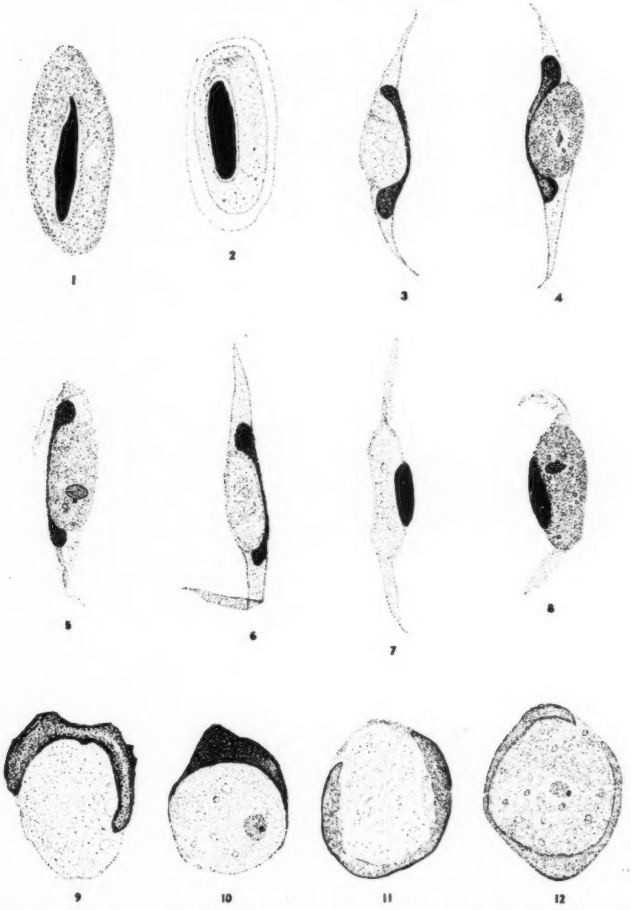

Plate 2. (Figs. 1-2 are x 1942; figs. 3-8 are x 800 and figs. 9-12 are x 1750.) Figs. 1-2. *Haemoproteus sacharovi* from the Mourning Dove. Showing macro- and microgametocytes that entirely enclose the host cell nucleus. (3-4) *Leucocytozoon ziemani* var. *nebraskensis* from the Screech Owl. Micro- and macrogametocyte. (5-6) *Leucocytozoon ziemani* var. *bubonis* Fantham from the Great Horned Owl. A macro- and microgametocyte. (7-8) *Leucocytozoon mathisi* var. *buteonis* from the Red-tailed Hawk. A micro- and macrogametocyte. (9-10) *Leucocytozoon beresineffi* Sambon from the Magpie. A micro- and macrogametocyte. (11-12) *Leucocytozoon laverani* Franca from the Blue Jay. A micro- and macrogametocyte.

to identify the species, or even the genus of duck with which they worked. Because of this nothing definite can be said about the host-specificity of this form nor can a definite decision be arrived at concerning the synonymy. It is apparent from this résumé of the literature that, if these two forms already described, are the same species the name *Leucocytozoon simondi* Mathis and Leger is the correct name for the parasite.

Leucocytozoon ziemani var. **nebraskensis** var. nov.

Pl. 2, Figs. 3-4

Laveran (1902) described and figured *L. ziemani* from *Athene noctua*. The description was rather meager, the only measurements given were of the total length of the host cell, and the figures do not show a karyosome in the female gametocytes. In 1903 Laveran gave a more detailed description of this species from the tawny owl, *Syrnium aluco*. In this paper he mentioned the presence of a karyosome and then gave the measurements of the female gametocytes. It should probably be pointed out that Laveran was undoubtedly dealing with two different species in the tawny owl, the spindle-shaped host cell type and the circular host cell type, which he treated separately but evidently considered to be identical.

Leucocytozoa have been found in each of three Screech Owls *(Otus asio)* examined. One of these birds was heavily parasitized. The parasites were found in spindle-shaped host cells which were drawn out to long sharp points. The cytoplasm of the host cell stained a pale bluish-pink, while the nucleus stained a deep rose. The latter structure was roughly dumbbell-shaped and fit over the parasite like a cap. There was very little difference in the measurements of the total length of the host cells. Host cells carrying female parasites varied from 37.17μ to 56.41μ with a mean of 46.70μ and those harboring male gametocytes 33.97μ to 55.13μ with a mean of 45.80μ.

The female gametocytes measured from 14.10μ to 18.59μ in total length and from 7.05μ to 10.27μ in width, with a mean size of 9μ by 16.34μ. The cytoplasm of the parasites stained blue and showed a large number of elliptical to circular vacuoles. A lighter staining area with a mean size of 5.01μ by 1.95μ was present around what was considered to be the nucleus. The nucleus which stained reddish-pink was elongate ovate to diamond-shaped. The measurements of the nucleus varied from 1.92μ to 4.81μ in total length and from 0.64μ to 1.28μ in width with a mean size of 3.07μ by 0.80μ. A karyosome could not be seen.

The male parasites had a total length of 14.74μ to 23.08μ and a width of 4.29μ to 9.62μ. The mean size was 18.01μ by 7.45μ. The body of the parasite stained pink. The nucleus was very diffuse and stained with about the same intensity as the cytoplasm so that in many cases its boundary was hard to determine. The mean size of the nucleus was 6.56μ by 5.82μ.

The parasites from the screech owl were carefully compared with all other named species described from owls. It was found that although this form does not fall within the measurement range of any of the described forms,

they fit the description of *L. ziemani* rather closely; but differ in that a karyosome can not be demonstrated and that the ends of the host cell are decidedly pointed.

Leucocytozoon ziemani var. *bubonis* Fantham
Pl. 2, Figs. 5-6

As pointed out in the discussion of the Leucocytozoon from the screech owl, Laveran (1902) named *L. ziemani*. The Legers' (1914) reported finding parasites of this genus in *Bubo lacteus* Tem. which they state compares favorably to *L. simondi* from a duck. Böing (1925) mentions having seen Leucocytozoon in *Bubo b. sibiricus* but he did not figure the parasites. Fantham (1926) described, but gave no figures, of a Leucocytozoon from *Bubo maculosus* which he designated as *L. ziemani* var. *bubonis*. The parasites described here from the Great Horned Owl *(Bubo virginianus)* hardly come within the range of measurements given for any of the named species but at the same time, do not differ markedly from Fantham's description of the variety *bubonis* and are in consequence considered as belonging to this variety of *L. ziemani*.

The host cells of the parasites from the great horned owl were spindle-shaped, but not drawn out into long sharp points. The cells carrying female parasites had a total length of 34.61μ to 58.97μ with a mean of 47.18μ and those with male gametocytes measured 39.10μ to 59.61μ with a mean length of 50.40μ. The host cell cytoplasm stained light pink and the nuclei a light red. The nucleus of the host cell was rather dumbbell-shaped, the connecting portion being drawn out to a narrow ribbon.

The female gametocytes stained blue, were rounded to elongate ovate and generally showed a few vacuoles. The elliptical nucleus stained a light red and was generally located at right angles to the long axis of the cell. A darker staining circular karyosome was present and lay decidedly off center. In many parasites this body appeared to be outside the nucleus although still in contact with it. The parasites measured from 13.46μ to 21.47μ in length and from 6.09μ to 13.14μ in width. The mean size was 17.74μ by 10μ. The length of the nucleus varied from 3.20 μ to 6.41μ and from 1.28μ to 2.56μ in width with a mean size of 4.62μ by 1.73μ. The mean size of the karyosome was 0.75μ.

The male parasites were generally longer and narrower than the females. These gametocytes stained a light blue and measured 13.78μ to 25.64μ in length and 4.81μ to 10.90μ in width with a mean size of 19.06μ by 6.62μ. The nucleus stained with almost the same intensity as the cytoplasm and was slightly reticular to diffuse. It measured 5.77μ to 14.42μ in length and 3.85μ to 8.65μ in width with a mean size of 9.19μ by 6.18μ.

Leucocytozoon mathisi var. **buteonis** var. nov.
Pl. 2, Figs. 7-8

There are six named species, all with spindle-shaped host cells, and numerous host records of Leucocytozoon from different genera of the family Accipi-

triidae which makes a list too long to be reviewed in full here. Only those species will be discussed which seem to have a direct bearing on the parasites from the Red-tailed Hawk *(Buteo borealis)*.

The description of *L. mathisi* França, 1912 from the European sparrow hawk, *Accipiter nisus* Linné corresponds very well with the material from the red-tailed hawk, a juvenile specimen, but comparison cannot be made on a basis of measurements for the reason that França failed to record this data and, in addition, gave no figures. Commes (1918) described *L. martyi* from *Astur badius sphenurus* Rüppel and records measurements of the parasites that fall within the range of the material from the red-tailed hawk. He further states that the host cells had long spindles which is hardly true for this material. Commes gave no illustrations. The only other named species which compares at all favorably is *L. laverani* Franchini, 1923. Franchini's measurements of the spindle-shaped forms do not fall within the range of our measurements but, the figures of these forms compare favorably. The bird from which Franchini obtained his material was evidently parasitized with both spindle-shaped and circular forms, because he gives measurements for both types and treats them as belonging to the same species. Even though Franchini's description did agree with the material under discussion, the species must be rejected because *L. laverani* was established in 1912 by França for a round form which he described from a jay, *Garrulus glandarius*. This, of course, makes *L. laverani* Franchini, 1923 a homonym of *L. laverani* França, 1912. In view of the fact that the parasites reported here do not fit the description of the described species, but do compare rather favorably with the species from *Accipiter nisus*, which is closely related systematically to *Buteo borealis*, it is proposed to designate these parasites as a new variety.

The parasites were located in rather blunt, gently tapering, spindle-shaped host cells. The host cells carrying female gametocytes measured 41.35μ to 51.28μ with a mean of 44.28μ and those with male parasites varied from 33.97μ to 57.69μ with a mean of 44.61μ. The nucleus of the host cells stained a dark blue. This body was compact, elongate ovate and lay partly enclosed by the gametocytes.

The female gametocytes were roughly bean-shaped, stained a dark blue and harbored a varying number of small vacuoles. These parasites measured 19.22μ to 23.72μ in total length and 6.09μ to 8.97μ in width. The mean size was 21.53μ by 7.56μ. The measurements for width were taken at a point about mid-way of the long axis of the parasite. At this point the width is actually less than if taken near the ends because of the depression in the parasite, as mentioned above. The nucleus was compact, roughly elliptical and stained red. This body occupied a position transverse to the long axis of the parasite. The mean size was 3.28μ by 2.40μ. Most of these parasites showed a small circular karyosome, which stained somewhat darker than the nucleus proper, lying at the periphery of the nucleus. The mean size of the karyosome was 0.82μ by 0.68μ.

The male gametocytes stained a light pink with slightly vacuolated cytoplasm. A nucleus could not be made out with certainty. The parasites

measured 16.67μ to 24.36μ in total length and 4.17μ to 7.69μ in width with a mean size of 20.64μ by 5.34μ.

Leucocytozoon berestneffi Sambon
Pl. 2, Figs. 9-10

The first record of a Leucocytozoon in the magpie was that of Sakharoff (1893). This author did not describe or discuss the parasites. Berestneff (1904) found a circular form in the same host. Sambon (1908) named the organism, found by the latter investigator, *L. berestneffi* but failed to give a description of the species. Leger (1917) reported this species from *Pica melonoleuca*. Böing (1925) discussed the Leucocytozoon which he found in *P. pica* at some length but gave no measurements. In this account an attempt has been made to present a rather detailed description, with figures of the Leucocytozoon from the Magpie *(Pica pica hudsonia)* which is considered to be *L. berestneffi* Sambon.

The host cells were of the round type and those harboring female parasites measured 10.80μ to 18.90μ in length and 8.10μ to 13.50μ in width. The mean size was 14.38μ by 10.87μ. The cells carrying microgametocytes measured 9.90μ to 18.00μ in length and from 6.97μ to 12.60μ in width. The mean size was 12.73μ by 9.82μ.

The macrogametocytes were typically circular to oval in outline but various forms may be found due to encroachment by red cells. These cells stained a dark bluish purple. The host cell nucleus partially surrounded the parasite and presented either a two-capped appearance or, looked rather like the letter C. The host cell cytoplasm had disappeared in most cases. The nucleus was elliptical and between 3μ to 5μ long. A karyosome was usually present. The parasites measured 8.55μ to 14.85μ in length and from 7.65μ to 12.60μ in width with a mean size of 11.26μ by 9.56μ.

The male parasites were partially enclosed by the host cell nucleus similar to that described for the macrogametocytes. The parasites stained pink. In length these forms measured 8.10μ to 12.60μ with a width of 6.30μ to 11.25μ. The mean size was 10.02μ by 8.38μ.

Leucocytozoon laverani França
Pl. 2, Figs. 11-12

França (1912) found a leucocytozoon in a jay, *Garrulus glandarius*, which he named *Leucocytozoon laverani*. This parasite was characteristically round or elliptical, although it sometimes presented a triangular or trapezoidal appearance. The size of the parasite was given as 7.5-10.5μ by 6-9μ. The parasite was surrounded by the nucleus of the host cell, or, in some cases, was lodged in a depression formed by the nucleus. The cytoplasm of the host cell had almost completely disappeared. The nucleus of the macrogametocytes was elliptical and measured 3μ in length and some showed a karyosome. Franchini (1924) recorded *L. laverani* from the same host species, *Garrulus glandarius*. One year later (1925) Böing recorded a Leucocytozoon from a

jay but did not figure it and Hamerton (1931) recorded leucocytozoa from the same host. The species reported here from the Blue Jay *(Cyanocitta cristata)* is evidently *L. laverani* França.

The parasites were rather scarce in the blood. The host cells were of the circular type and those harboring macrogametocytes measured 11.70μ to 18.00μ in length and from 8.10μ to 13.95μ in width. The mean size was 15.81μ by 11.35μ. The host cells carrying microgametocytes measured 12.60μ to 17.55μ in length and from 8.10μ to 13.50μ in width with a mean size of 14.91μ by 10.73μ.

The female parasites were typically round or oval. Numerous individuals were found broken out of the host cells. The cytoplasm of the host cell had practically disappeared. The nucleus of the host cell typically formed a C around the parasite and some specimens appeared to have a cap of nuclear material at each end of the parasite but a thin band of chromatin connected these two caps, thus maintaining the nuclear unity. The nucleus of the macrogametocytes was elliptical and between 3 and 4μ long. A karyosome was present in the majority of specimens. In several specimens granules appeared in the cytoplasm but careful observation showed that they were not pigment granules since most of then tinted red with eosin. The parasites measured 9.00μ to 14.85μ in length and 8.10μ to 13.05μ in width. The mean size was 11.97μ by 9.77μ.

The microgametocytes were typically round, but the form varied some because of crowding by erythrocytes. The cytoplasm of the host cell had in most cases disappeared. The host cell nucleus usually partly surrounded the parasite, producing a two-capped appearance as noted for the female parasites. The microgametocytes measured 12.60μ to 17.55μ in length and 8.10μ to 13.50μ in width. The mean size was 11.74μ by 8.59μ.

Plasmodium Marchiafava and Celli

As mentioned earlier, under *H. picae*, this Magpie *(Pica pica hudsonia)* was heavily parasitized with plasmodia when brought to the laboratory in November, 1936. Careful study of the blood picture showed two kinds of gametocytes present, one round and the other of the elongate type. In order to facilitate the study of these malarias attempts were made to infect the canary. The blood was given intravenously and infections with the type having round gametocytes were obtained. This species was tentatively identified as *P. cathemerium* and the identification later confirmed by Dr. C. G. Huff of the University of Chicago. This strain from the magpie is decidedly pathogenic for the canary. So far, attempts to produce the infection by the intramuscular route have been unsuccessful. On two occasions attempts were made to infect the pigeon with this strain but without success.

The strain having elongate gametocytes was rather scarce in the blood. The schizonts were elongate and generally had eight merozoites. The host cell nucleus was decidedly displaced. The gametocytes had a tendency to displace the host cell nucleus and to curve around it.

The elongate gametocytes disappeared from the blood of the magpie on the third day after the bird was brought under observation and at the end of eight days *P. cathemerium* could not be found in the smears. Smears have been made at intervals of about a week all during the winter and so far there has been no evidence of relapse. The bird is still under observation at this writing.

Plasmodia have been found in three other species of birds during the course of this survey. The identification was based on smears alone. *Plasmodium praecox (relictum)* has been found in a crested flycatcher *(Myiarchus crinitus)*. *Plasmodium vaughni*, or a closely related species, was found in a Blue Jay *(Cyanocitta cristata)* and in a fledgeling Robin *(Turdus migratorius)*. The finding of malaria in a young robin is of interest, especially because of the recent survey work of Manwell and Herman (1935a). These authors examined twenty robins, including ten young birds. All of the adults were found carrying malaria but none of the young birds were infected, which led them to suggest "that the disease is generally acquired later in life, and very likely in the winter habitat." With the finding of a young robin infected upon leaving the nest it is probably safe to assume that, at least in this region of the United States, the vector is present during the nesting season and that the robins may acquire the infection at that time. It is indeed regrettable that no canaries were available for sub-inoculation when these plasmodia came to hand.

Trypanosoma Gruby, 1843

Trypanosoma avium Danilewsky

Pl. 3, Figs. 1-16

The first authentic record and description of a trypanosome in birds was *Trypanosoma avium* Danilewsky (1885). The character of the parasites found by that author was such that he described two distinct sizes of the species. According to Novy and MacNeal, Danilewsky (1888) named the smaller one, which varied from 18-22μ (excluding the flagellum), *T. minus*, and the larger, which measured 45-60μ, *T. majus*. Laveran (1903a) found a trypanosome in an owl, *Syrnium aluco*, which he described and designated as *T. avium*. Laveran's trypanosome measured 33-45μ, including the flagellum.

Novy and MacNeal (1905) found both forms of *T. avium* in a number of North American birds. The larger form, with myonemes, they described as having the following measurements, in the living state: length of body from 21μ to 40μ, length of the flagellum from 10μ to 15μ, width of the body at the nucleus from 5μ to 7μ. Stained specimens varied in body length from 35μ to 65μ; the flagellum was said to be probably from 15μ to 20μ in length. The smaller form varied, in the living state, from 25μ to 30μ in total length, from 14μ to 25μ in body length, and from 8μ to 12μ in length of the flagellum. Width varied from 3.5μ to 5μ. Stained specimens were 20μ to 25μ in length of body. The parabasal body was located from 1μ to 5μ from the posterior end.

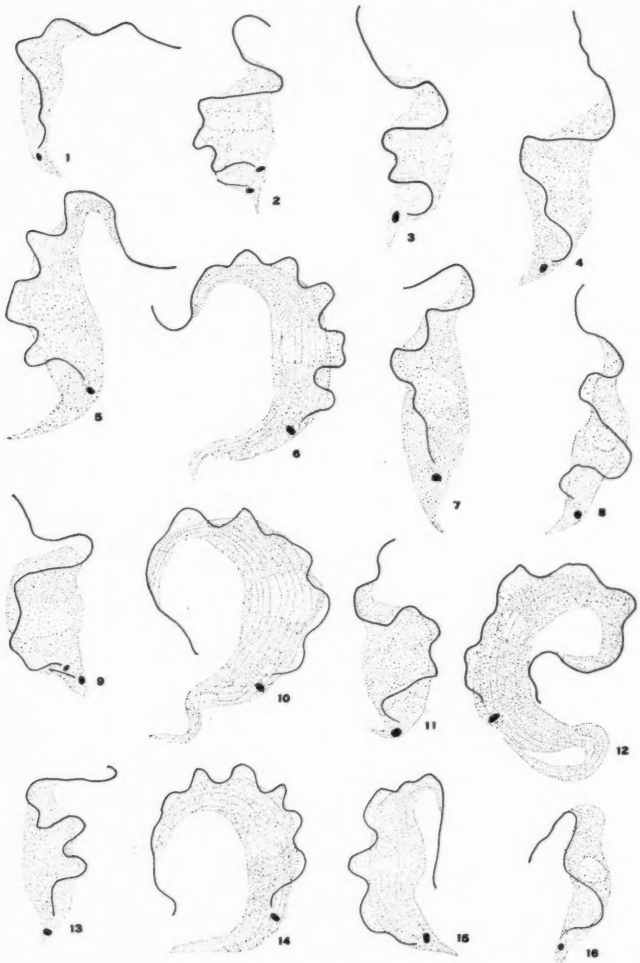

Plate 3. *Trypanosoma avium* x 1480. Figs. 1-6. *T. avium* from the Baltimore Oriole. These figures show the various steps in the change from one morphological type to the other. Fig. 2 shows a specimen in division. Fig. 5 is the larger type of the non-myonemed form and closely resembles Fig. 6 which is a typical myonemed individual. (7) *T. avium* from the Black-billed Cuckoo. Only form found. (8) *T. avium* from the Blue Jay. Only form found. (9-10) *T. avium* from the Red-breasted Grosbeak. Both forms found. (11-12) *T. avium* from the Yellow-billed Cuckoo. Both forms. (13-14) *T. avium* from the Dickcissel. Both forms. (15) *T. avium* from the Great-Horned Owl. Only specimen found. (16) *T. avium* from the Purple Martin. Only form found.

In the material collected for the present work, trypanosomes have been found in two Baltimore Orioles *(Icterus galbula)*, one Dickcissel *(Spiza americana)*, two Rose-breasted Grosbeaks *(Hedymeles ludovicianus)*, two Yellow-billed Cuckoos *(Coccyzus a. americanus)*, one Black-billed Cuckoo *(Coccyzus erythrophthalmus)*, one Blue Jay *(Cyanocitta cristata)*, one Purple Martin *(Progne subis)* and a single trypanosome in the Great Horned Owl *(Bubo virginianus)*. All of these trypanosomes are being considered as belonging to *Trypanosome avium*. The specimen from the owl is not considered in the table nor in the discussion, the reason for this will be explained later. Both the large myonemed and the small, non-myonemed forms of *T. avium* were found in most of the birds except the black-billed cuckoo, the blue jay and the purple martin, in which only the small forms were found. The great horned owl had only a myonemed specimen present.

The large form with myonemes was found to have a rather short flagellum and a wide undulating membrane which had a large number of undulations. This membrane rarely crossed the body and in one case where it did cross over, the specimen was badly contorted. (Plate 3, Figs. 6, 10, 12, 14) The nucleus was situated near the middle of the body and in most cases appeared as a circular or oval area which stained red or pink. Parabasal bodies were usually round or elliptical and stained a deep red. The parabasal body was located about one-fourth to one-third of the length of the body from the posterior end. The cytoplasm stained a deep blue and the myonemes appeared as thin lines the full length of the body and were most prominent in the region of the nucleus. Specimens, in the majority of cases, showed the presence of a small vacuole just anterior to the parabasal body. The size and relative measurements of the specimens from the various birds may be seen in Table 1.

The small forms, without myonemes, varied in structure. (Plate 3, Figs. 1-5, 7-9, 11, 13, 16) The predominant forms were spindle-shaped and had relatively long flagella. The undulating membrane had few undulations. The parabasal body was situated closer to the posterior end of the cell than in the large form. Like the larger form, a small vacuole is sometimes present anterior to the parabasal body. The nucleus was about in the center of the body and it stained red in most cases. Other forms closely resembled the myonemed form both in size and structure except for the total absence of myonemes. (Plate 3, Fig. 5) Because of the lack of myonemes they have been placed in this second group. These specimens raise the range in size in the smaller forms, especially in the case of the Baltimore oriole and the yellow-billed cuckoo. Table 2 gives the measurements for these specimens.

The fact that the non-myonemed form has, in the upper extremity of its size range, forms which, except for the lack of myonemes, are indistinguishable from the myonemed form shows that there is a rather close relationship between the two forms. To be more specific it indicates that one gradually changes form and ultimately becomes the other. This change can easily be followed in the trypanosomes from the Baltimore oriole, for which reason the figures showing the transition are made from that host (Plate 3, Figs. 1-6).

TABLE 1

Trypanosoma avium

with Myonemes

Measurements of Specimens from Various Hosts

		Baltimore Oriole	Dickcissel	Rose-Breasted Grosbeak	Yellow-billed Cuckoo (one specimen)	Totals for all Specimens
Posterior end to middle of parabasal body	Range	9.45–13.50μ	9.90–13.50μ	12.60–18.00μ		9.45–18.00μ
	Aver.	11.23μ	11.50μ	16.20μ	22.50μ	12.20μ
Middle of parabasal body to middle of nucleus	Range	6.30– 8.10μ	6.75– 9.00μ	8.10–10.80μ		6.30–10.80μ
	Aver.	7.38μ	7.84μ	9.00μ	9.00μ	7.64μ
Middle of nucleus to anterior end of body	Range	14.20–18.90μ	14.40–18.90μ	19.80–22.50μ		14.20–22.50μ
	Aver.	17.04μ	16.13μ	20.88μ	21.60μ	17.41μ
Length of Flagellum	Range	3.78– 8.10μ	4.95– 7.65μ	4.95– 9.45μ		3.78– 9.45μ
	Aver.	5.86μ	6.10μ	6.66μ	7.20μ	6.04μ
Length	Range	37.15–45.90μ	38.70–46.80μ	45.45–57.25μ		37.15–60.30μ
	Aver.	41.53μ	41.59μ	52.94μ	60.30μ	43.48μ
Width	Range	3.60– 6.30μ	3.15– 5.58μ	4.05– 7.65μ		3.15– 7.65μ
	Aver.	4.88μ	4.14μ	5.71μ	4.50μ	4.85μ

TABLE 2

Trypanosoma avium

without Myonemes

Measurements of Specimens from Various Hosts

		Baltimore Oriole	Dickcissel	Rose-breasted Grosbeak	Yellow-billed Cuckoo	Black-billed Cuckoo	Purple Martin	Blue Jay	Totals for all Specimens
Posterior end to to middle of parabasal body	Range	1.35– 9.90μ	1.35– 2.25μ	0.90– 3.60μ	1.35– 9.00μ	4.50– 8.10μ	2.25– 3.15μ	3.60– 4.50μ	0.90– 9.90μ
	Aver.	4.77μ	1.80μ	2.48μ	3.69μ	6.15μ	2.84μ	3.96μ	3.90μ
Middle of parabasal body to middle of nucleus	Range	4.95– 9.90μ	5.40– 9.90μ	6.30– 9.90μ	6.30– 9.90μ	7.20– 9.00μ	7.65– 8.10μ	7.20– 9.00μ	4.95– 9.90μ
	Aver.	8.16μ	8.64μ	7.70μ	8.33μ	8.44μ	7.87μ	8.06μ	8.23μ
Middle of nucleus to anterior end of body	Range	8.10–18.45μ	7.20– 9.45μ	6.30–11.70μ	7.65–13.50μ	9.90–13.50μ	9.00–10.80μ	9.45–11.25μ	6.30–18.45μ
	Aver.	11.58μ	7.83μ	9.50μ	10.89μ	11.88μ	10.12μ	10.26μ	10.78μ
Length of Flagellum	Range	4.50–10.80μ	5.85– 8.10μ	4.68–12.15μ	3.60–12.15μ	4.50–10.80μ	4.50– 5.40μ	6.75– 9.00μ	3.60–12.15μ
	Aver.	6.69μ	7.02μ	7.24μ	7.28μ	7.08μ	4.95μ	7.98μ	7.13μ
Length	Range	24.30–41.85μ	22.50–27.90μ	23.40–30.15μ	24.30–37.35μ	28.35–38.70μ	24.75–26.55μ	28.80–32.40μ	22.50–41.85μ
	Aver.	31.21μ	25.29μ	26.96μ	30.20μ	33.56μ	25.95μ	30.24μ	30.05μ
Width	Range	3.15–10.35μ	3.78– 7.20μ	2.70– 8.10μ	3.15– 9.45μ	4.50– 6.30μ	3.60– 7.20μ	3.60– 7.65μ	2.70–10.35μ
	Aver.	5.61μ	5.07μ	5.18μ	5.28μ	5.29μ	4.95μ	4.97μ	5.32μ

The direction in which this process takes place is difficult to prove, from the study of stained preparations made after the death of the bird. Because of this, no attempt will be made to establish whether the small form develops into the large or *vice versa,* however, evidence on both sides of the question will be advanced.

Novy and MacNeal believed that the large form was similar to the large parasites found in the early stages of an infection with *T. lewisi* and concluded that they developed into the short non-myonemed form. To substantiate this view they said, "the position of the blepharoplast with reference to the nucleus clearly shows that the large form is to be considered as preparing for division. Furthermore, the presence of this type in very young birds indicates that the infection is of recent origin." Later in the same paper these authors record the measurements and descriptions of trypanosomes found in the blood of an experimentally infected canary which had been infected four days. These trypanosomes were in the shape of a long straight spindle and were about 4.5μ wide and 28μ long, the flagellum measured 12-15μ. The undulating membrane of the specimens was conspicuous and passed over the body in two large waves. No mention is made of the presence or absence of myonemes (See Plate 3, Fig. 4). Later in this same bird a trypanosome, measuring 17μ long, 3-4μ wide and with a flagellum 8μ long was found. (Since all of these observations were made on living material it is probable that the measurements were not exact.)

One of the chief differences between the two forms, which could have been noticed in the living condition was the number of undulations in the membrane. As stated above, they recorded the first specimens found as having an undulating membrane in which only two large waves occurred. From the description of the trypanosomes in the canary it can be seen that the form first observed resembled the small forms (See Plate 3, Fig. 4). The specimen found later in the same bird cannot be definitely associated with either form.

The statement made by Novy and MacNeal about the position of the blepharoplast showing that the large form was preparing for division, is a curious observation with regard to the present findings. In no case was a specimen with myonemes found to be in any state of division i.e. having any parts doubled or even having evidences of doubling them. Instead the opposite was found. Several small non-myonemed forms were found with two parabasal bodies and at least the beginning of a second undulating membrane.

Huff (1937) found both the myonemed and the non-myonemed forms in the blood of a Bluebird *(Sialia sialis).* Here also, only the non-myonemed forms were found in division.

These scattered facts make the evidence on one side or the other far from conclusive and so it is felt that this should remain a debatable point until someone has satisfactorily followed the development from one stage to the other.

The trypanosome *(T. avium)* from the great horned owl was from a bird

being treated with atebrine and since the action of that drug on trypanosomes is unknown to the authors it was deemed advisable not to average it with the others. The measurements for the specimen were as follows:

Posterior end to middle of parabasal body	3.60μ
Middle of parabasal body to middle of nucleus	7.65μ
Middle of nucleus to anterior end	13.50μ
Length of flagellum	7.20μ
Total length	31.95μ
Width	5.40μ

Mynonemes were present on the body but they were extremely light compared with those on other specimens.

Microfilaria Cobbold, 1880

Microfilaria have been found in seven species of birds belonging to five genera. Those from the Baltimore Oriole *(Icterus galbula)* varied in total length from 67.31μ to 91.66μ with a mean of 80.77μ. The maximum width was 3.81μ. The animal was slightly drawn away from the sheath at the anterior end leaving a small clear zone. The anterior end was smoothly rounded and blunt; the posterior, tapering but blunt also.

The Orchard Oriole *(Icterus spurius)* carried a much larger form than the one from the Baltimore oriole with a mean length of 166.5μ and a maximum width of 6.33μ. A small clear zone was visible at the anterior end between the animal and the sheath. Both ends were blunt.

One Red-breasted Grosbeak *(Hedymeles ludovicianus)* showed numerous microfilarial forms with a varying length of from 324.6μ to 419μ with a mean length of 365.5μ. The maximum width was 10.55μ. The sheath fitted tightly over the rounded anterior end of the parasite and the posterior end tapered to a point.

Both the Yellow-billed and the Black-billed Cuckoo *(Coccyzus a. americanus)* and *(C. erythropthalmus)* showed numerous microfilaria which were morphologically indistinguishable. The length of these forms varied from 99.9μ to 109.89μ in total length with a mean of 103.48μ. The maximum width was 5.32μ. The worms were rather thick-set and blunt at the anterior end. The posterior end was tapered to a point.

A few microfilarial forms were found in the blood of the Mourning Dove *(Zenaidura macroura carolinensis)*. With these parasites the anterior end was blunt while the posterior region tapered to a point. A sheath was not visible. The parasites had a mean length of 80.3μ and a maximum width of 4.36μ.

The microfilaria from the Magpie *(Pica p. hudsonia)* was decidedly blunt at the anterior end. The width of this region was equal to that of any other part of the parasite. The posterior region was tapering but blunt at the end. The parasite measured 121.6μ in length and had a maximum width of 4.81μ.

The following birds were negative for blood-inhabiting organisms (PERU REGION): (4) Long-tailed Chicadee *(Penthestes atricapillus septentrionalis)*; (4) (1 juv., 3 ad.) Red-headed Woodpecker *(Melanerpes erythrocephalus)*;

(3) Eastern Kingbird *(Tyrannus tyrannus);* (2) Dickcissel *(Spiza americana);* (2) Migrant Shrike *(Lanius ludovicianus migrans);* (2) Downy woodpecker *(Dryobates pubescens);* (3) (2 juv., 1 ad.) Northern Flicker *(Colaptes auratus luteus);* (1) Red-bellied Woodpecker *(Centurus carolinus);* (2) Chimney Swift *(Chaetura pelagica);* (1) Indigo Bunting *(Passerina cyanea);* (2) Eastern Red-wing *(Agelaus phoeniceus);* (1) juv. Robin *(Turdus m. migratorius);* (1) Orchard Oriole *(Icterus spurius);* (1) Magpie *(Pica p. hudsonia);* (1) Bronzed Grackle *(Quiscalus q. aeneus);* (2) Fox Sparrow *(Passerella iliaca);* (1) Sharp shinned Hawk *(Accipiter velox);* (1) Swainson's Hawk *(Buteo swainsoni);* (2) Barn Swallow *(Hirundo erythrogaster);* (1) juv. Mourning Dove *(Zenaidura macroura carolinensis);* (1) juv. Cardinal *(Richmondena cardinalis);* (2) Blue Jay *(Cyanocitta cristata);* (2) Tufted Titmouse *(Baeolophus bicolor);* (5) English Sparrow *(Passer d. domesticus);* (5) juv. Purple Martin *(Progne subius);* (1) Towee *(Pipilo* sp.); (1) Catbird *(Dumatella carolinensis).*

(Lincoln Region): (1) Western Willet *(Catoptrophorus semipalmatus inornatus);* (1) Orchard Oriole *(Icterus spurius);* (1) Cooper's Hawk *(Accipiter cooperi);* (1) Cedar Waxwing *(Bombycilla cedrorum);* (1) Kentucky Warbler *(Oporornis formosus);* (1) Northern Crested Flycatcher *(Myiarchus crinitus boreus);* (1) Eastern Lark Sparrow *(Chondestes grammacus);* (1) American Rough-legged Hawk *(Buteo lagopus s. johannis);* (1) Wood Pewee *(Myiochanes virens);* (1) Dickcissel *(Spiza americana).*

(Valentine Region): (1) Great Blue Heron *(Ardea h. herodias);* (1) Black-billed Cuckoo *(Coccyzus erythropthalmus).*

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Notes on the Natural History of Several Marine Crustacea

G. E. MacGinitie

Unless otherwise stated, the animals referred to below were found in Newport Bay, California, at the entrance to which the Kerckhoff Marine Laboratory is located, or in the ocean in this vicinity. Except in those instances in which the animals were collected elsewhere, the observations were made at this laboratory, or on the animals in their natural habitat in the field.

Copepoda

Peniculus fissipes Wilson, an elongated copepod (Pl. 1, Fig. 7) which I found ectoparasitic on the two fishes *Girella nigricans* (Ayres) [common name, Opaleye], and *Hypsypops rubicundus* (Girard) [the Garibaldi], has a reversal of heart action. The heart is an elongated tube, which extends even into the head. Several peristaltic movements pass along the heart from the posterior to the anterior end, then the peristalsis reverses so that the movements go from the anterior to the posterior end. The latter movements are the weaker, but are very definite. The number of peristaltic movements passing in either direction is highly variable, but those which travel in an anterior direction are more numerous than the posteriorly moving ones, so that the blood travels anteriorly for a longer period than it does posteriorly. Occasionally while the peristalses are moving posteriorly, from one to three successive weak movements may originate in the posterior region, but they travel anteriorly only a short distance before dying out upon meeting those traveling posteriorly.

Tisbe furcata, a tiny copepod averaging about 0.7 mm. in length, and which is very common in the aquaria at this laboratory, particularly when there is any decaying seaweed about, completes its life cycle in ten days.

Isopoda

The mullets *(Mugil cephalus* Linnaeus) taken from Newport Bay nearly always have a pair of isopods, *Meinertia* sp. (new sp.), clinging to their tongues. The female isopod is several times larger than the male (Pl. 1, Fig. 1), and the two practically fill the buccal cavity of the fish. The mullet does not use solid food, but sucks mud from the bottom for the organic material which it contains.

Decapoda

Molting, Growth, and Housing

Przibram (1901, 1907) found that in certain decapods in which either the right or left cheliped is larger than the other, the small cheliped will develop into the large one if the large cheliped is removed. Morgan (1923)

found that the fiddler crab *(Gelasimus)* of the Atlantic coast does not reverse hands if the larger one is removed, for in this case the "new large claw regenerates on the stump of the old one."

In the pistol shrimp, *Crangon californiensis* (Holmes), the large cheliped or pistol hand (Pl. 1, Fig. 2) may be either right or left. In the case of this shrimp I have found that if the pistol hand is removed a reversal of the hands takes place and is completed within five weeks. The pistol hand of this shrimp is much more important for food getting activities (see below under "Food Habits") than is usually the case with crustacea of this type, and quick reversal is no doubt a great advantage.

When this shrimp molts, the exoskeleton from the pistol hand and the joints back of it splits and flakes off, and the hand is not pulled out as is the case with the lobster (Herrick, 1895) and the brachyuran crabs. Herrick (1895, p. 207) noted this splitting of the exoskeleton of the pistol hand in a single specimen of *Crangon (Alpheus) dentipes*, but apparently there was no flaking off.

Growth and reversal of the hands of *Crangon californiensis* was, in those cases which I observed, always accompanied by a complete ecdysis, so that there is an indication that the mutilation stimulated molting. Those individuals from which the large cheliped was removed molted and reversed hands within five weeks as stated above. The controls in this experiment did not molt during this time, nor for some time afterward. There is also an indication that mutilation stimulates molting in other forms, such as the spiny lobster and certain tide pool shrimps, and experiments are now under way to determine this point.

The abdomen of hermit crabs is flexed to the right, with the appendages along the right side either missing or degenerate. This flexing to the right is, no doubt, because, with few exceptions, the snail shells which these crabs inhabit, and which they have used throughout their evolutionary development, spiral to the right. I have often dredged specimens of *Paguristes turgidus* Stimpson which were inhabiting the shells of the gastropod *Antiplanes perversa* Gabb, which spiral to the left. These hermit crabs seemed to be perfectly at home in the left-handed shells, though they normally inhabit those which turn to the right. After being taken from the left-handed shell, their abdomens are found to flex to the right in the normal manner, as though they had just been removed from a right-handed shell.

Since hermit crabs are symmetrical as larvae, it may be thought that the use of the shell during growth causes the asymmetry (Thompson, 1904), and this may be the case to a certain extent. However, hermit crab larvae that have come into our salt water storage tank have been allowed to develop there for as long as two years. These crabs never experienced the use of a snail shell for their house, yet their abdomens curled as tightly to the right as do those of hermits which have always used such shells.

The tiny hermit crab, *Pylopagurus minimus* (Holmes), which has a long, fairly straight abdomen, generally uses the shells of *Dentalium* (tooth shells) for its home. On June 21, 1932, I dredged from Monterey Bay, California,

two of these small hermits which had their abdomens inserted into opposite ends of the same short piece of worm tube. (Pl. 1, Fig. 6). This double ended arrangement was strictly a disadvantage, for the crabs were of about the same size, and, since they usually tried to proceed in opposite directions little or no progress could be made.

Decorating Habits

Many crabs possess the instinctive habit of covering their bodies and legs with bits of seaweed until it is very difficult to detect their presence. They decorate themselves by breaking the seaweed into bits, holding a portion for a moment to the mouth to add a glue-like secretion, and then placing it on the body or legs, where it adheres. *Loxorhynchus grandis* Stimpson, our largest spider crab on the coast of Southern California, possesses this habit as a juvenile, but, when it reaches a size of about three inches across the carapace, it gradually loses the instinct to camouflage itself in this manner. The largest *Loxorhynchus grandis* which I have taken was a male with a carapace 268 mm. long and 214 mm. wide. When juveniles of this species in aquaria at the laboratory are deprived of seaweed, they will decorate themselves with whatever they can get and tear apart for this purpose. I have seen them use the empty egg cases of the gastropod, *Bursa californica* (Hinds); the freshly laid ones of *Kellettia kellettii* Forbes; portions of the egg strings of the sea hare, *Tethys;* pieces of sea pansies, and even flakes of asphalt which they tore from the blank wall of the aquarium. Needless to say, in some such cases the crab was much more conspicuous with its covering than without it.

Food Habits

The destructive powers of the chelae of *Loxorhynchus grandis* are not limited to preparing coverings for its body, but are also used to take other animals apart for food. If an individual of this species is confined in an aquarium with an octopus, it will take the octopus apart and devour it piece by piece. I have seen *L. grandis* tear up even a starfish, *Pisaster giganteus* (Stimpson), and laboriously pick out the tiny edible particles from the hard portions.

The large cheliped or pistol hand of *Crangon californiensis* (Holmes) is used for both offense and defense, and the food of this shrimp consists of whatever it is able to "shoot." In the laboratory at least, and I believe this is also true in the field, the pistol shrimp lies in wait just within the entrance of its burrow, and, by snapping small animals with the movable thumb or "hammer" of the pistol hand, kills or stuns them as they pass by. The prey is then drawn into the burrow and devoured partially or entirely, depending upon its size. The shrimp discards the refused portion by shoving it outside the entrance of the burrow. Sometimes the prey may be seized by the small chela of the opposite hand, and then, either while still at the entrance of the burrow or after it has been dragged inside, the prey may be struck with the pistol hand to quiet it. Many *Clevelandia ios* (Jordan and Gilbert) and the young of *Gillichthys mirabilis* Cooper are killed by these shrimps in this man-

ner. *C. ios* and *G. mirabilis* are fish belonging to the family *Gobiidae*, and are indigenous to salt water estuaries along this coast.

Many of the pinnotherid crabs, practically all of which are commensal, depend upon the currents of water maintained by their hosts for respiration to bring them food. While many of them will eat solid particles, the majority are also able to fan plankton or detritus from the current by use of their maxillipeds. *Pinnixa franciscana* Rathbun (Pl. 1, Fig. 4), which lives commensally with such burrowers as *Urechis, Upogebia,* and *Callianassa,* uses this method almost entirely as a means for obtaining its food (MacGinitie, 1935, p. 716).

An extreme of the divergent methods of using either solid food or plankton is exemplified by the brachyuran *Lopholithodes foraminatus* (Stimpson). (Pl. 1, Fig. 5). This crab is equipped with powerful mandibles for crushing such pelecypods as *Nucula, Leda,* and *Venericardia,* yet, when deprived of the opportunity of obtaining these clams, it will fan plankton, often stirring the mud with its chelae to enrich the food supply of the current.

The hermit crab *Pagurus ochotensis* Brandt also uses both solid material and detritus for food, but mainly the latter. Sand or mud is stirred up by alternate movements of the chelipeds, while the second maxillipeds continually fan through the stirred-up material. As feeding is carried on, the crab moves forward about a centimeter at a time.

When resting, this hermit crab partially buries itself in the sand. To accomplish this the hermit, using its second leg for an anchor, forces it well down into the sand, and then, with its chelipeds, pushes the sand forward from under itself. The burrowing is sufficient to allow about two thirds of the shell to be covered, leaving about half of the opening above ground.

Pairing in Marine Animals

Judging from my experience, there are but two groups of marine animals among which the male and female live in pairs for any length of time. These two groups are the crustacea and the fishes.

Among the crustacea of the west coast of North America I have observed several species which pair off permanently. This pairing habit in *Upogebia pugettensis* (Dana) has already been discussed in previous papers (MacGinitie, 1930; 1935, p. 706). A male and female *Callianassa affinis* Holmes, a very close relative of the mud shrimp, *C. californiensis* Dana, also live together in pairs under permanent conditions. The natural history of the latter species, which does not live in permanent pairs, has also been discussed in other papers (MacGinitie, 1934; 1935, p. 709). Because *C. affinis* resembles *C. californiensis* so closely, one would naturally suppose that it would live in a manner similar to that of *C. californiensis*. The fact that *C. affinis* does not live as does *C. californiensis* exemplifies the rule that should be a part of the mental equipment of all field workers; namely, it is unsafe to judge the natural history activities of one species by those of another species, no matter how closely related they may be.

Callianassa affinis lives in burrows in the sand which lodges among the rocks on the exposed beaches along the rocky shores of Southern California. A burrow always contains a male and female *Callianassa*. They strain their food from the water which they pump through the burrow, and, therefore, their habits of living are very similar to those of *Upogebia pugettensis* mentioned above.

Pachycheles rudis Stimpson, *Pachycheles holosericus* Schmitt, and *Oedignathus inermis* (Stimpson), anomuran crabs, are practically always found in pairs. Paired *P. rudis* live in the crevices of rocks, in the holdfasts of algae, or any similar location where a current of water will wash through their burrows. They obtain their food by fanning plankton from the water with their maxillipeds, which are especially equipped with appendages (Pl. 1, Fig. 3) for performing this function. (Also see Nicol, 1932, and Orton, 1921, 1927, on methods of feeding in other crabs.) *Oedignathus inermis* is found paired mainly under the incrusting pinkish-purple corralline alga which covers the rocks at about the low tide mark, though it is also found under conditions similar to those in which *P. rudis* lives. It obtains its food in the same manner as does *P. rudis*. (The observations on *Oedignathus inermis* and *Pachycheles rudis* were made at Pacific Grove, California, while I was at the Hopkins Marine Station.)

Paired *Crangon californiensis* (Holmes) are very plentiful in the mud flats of estuaries along the coast of Southern California, where they make burrows among the shells or among the roots of *Zostera*. Male and female *Crangon dentipes* also live in *pairs*, but they build their burrows on the under sides of rocks on the open beach. *Crangon californiensis* has been found living commensally in pairs in the burrows of the echiuroid, *Urechis caupo* (MacGinitie, 1935, p. 682).

Many semiparasitic or commensal isopods pair permanently, as is exemplified by *Meinertia* (see above), *Phyllodurus*, and *Argeia*. In fact, in the family *Bopyridae*, to which the two latter genera belong, pairing is the rule rather than the exception. Several other families of isopods have representatives which pair permanently. (See Richardson, 1905, for hosts of these isopods.) The evolutionary development of the pairing instinct among crustacea which are dependent upon a single host for their existence beyond the larval stage is more easily accounted for than it is among the free-living forms. Among crustacea, mating is necessary to propagation and, therefore, the convenient arrangement of the paired condition is undoubtedly a great advantage. It is interesting to note in this connection that in the case of these paired semiparasitic or commensal isopods, the male is much smaller than the female, and thus space is conserved where space is valuable.

Although the evidence is not complete, I believe that *Betaeus londigactylus* Lockington also lives permanently paired in burrows under rocks along the beach, and commensally with *Upogebia* and *Urechis* (MacGinitie, 1935). I have found many pairs of a new species of *Betaeus* living commensally with

Callianassa californiensis, in estuaries along the coast of Baja California, Mexico. This latter instance of pairing is interesting because the *Betaeus* remains paired, although the particular host and burrow are not permanent indefinitely.

The blind goby, *Typhlogobius californiensis* Steindachner, lives in pairs in the burrows of *Callianassa affinis* mentioned above. The natural history of this fish is being written in detail for future publication.

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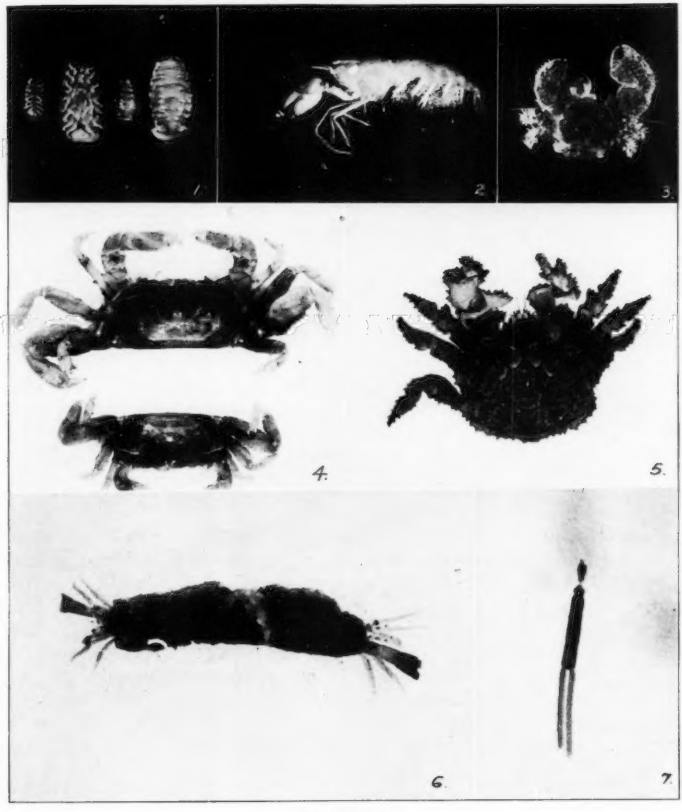

PLATE 1

FIGURES

1. *Meinertia* sp. (n. sp.), male and female. x 3/8.
2. *Crangon californiensis* (Holmes). x 1/2.
3. *Pachycheles rudis* Stimpson, showing "food strainers" of the maxillipeds.
4. *Pinnixa franciscana* Rathbun, male and female. x 1/2.
5. *Lopholithodes foraminatus* (Stimpson), ventral view. x 1/6.
6. *Pylopagurus minimus* (Holmes). Two individuals inhabiting the same tube.
7. *Peniculus fissipes* Wilson, female. x 4.5.

Observations on the River Shrimp, Macrobrachium ohionis (Smith)

Gordon Gunter

As little other than the anatomy (McCormick, 1933) is known of this interesting and somewhat commerically valuable crustacean, the writer has brought together here the results of certain studies which were conducted at Port Allen, Louisiana from October 1, 1933 to January 21, 1934 under the joint auspices of the Department of Conservation and the State University, and which were discontinued on July 7, 1934 before the original plan of working out the animal's life history could be completed.

I am indebted to these same authorities for assistance and to Mr. Frank Chapman for specimens collected at Port Allen in the interval between January 21 and July 7, 1934; to Mr. Milton J. Lindner, of the Shrimp Investigations, U. S. Bureau of Fisheries, for the use of data on the migration of the shrimp into salt water obtained by myself in 1932 and 1933; and to Mr. J. Nelson Gowanloch, of the Louisiana Department of Conservation, for salinity readings made at the same time by Mr. Forrest V. Durand.

Macrobrachium ohionis is most common in and around the Mississippi River, and so far as recorded, occurs in that river from Illinois to the Gulf of Mexico. It has also been reported from Georgia and North Carolina on the east and the Lavaca River in Texas on the west (Schmitt, 1933), but its distribution is still imperfectly known. It has been used for food for many years, probably long before it was known to zoologists. Smith, in his description of the species in 1874, mentions its economic use. In Louisiana many fishermen along the Mississippi derive part of their income during the summer months from the catch of *M. ohionis*. As sales are often made from door to door no adequate statistics of the catch are available. It is believed to amount to several thousand pounds a year.

Commercially, the shrimp are taken in box traps made of wood strips, baited with fish and meat scraps, and sunk in shallow water not far offshore. These traps have an inverted V-shaped inset running lengthwise along the bottom of the box with an open groove at the angle of the V. Pressed cottonseed cake is sometimes used as bait, but fishermen state that decayed meat is better and is more frequently used. The cottonseed cake is often sprinkled on the shrimp before they are taken to market, in order to make the fastidious buyer believe the less objectionable bait had been used. Shrimp attack fish kept alive in live-boxes in the river, feeding on whatever part of the body to which they happen to attach. Catfish are especially vulnerable and are often virtually skinned alive. Live-boxes are therefore covered with screenwire to protect the fish.

Shrimp are sometimes captured by lifting willow bushes out of the water

and catching the animals in a dip net as they drop off. McCormick (1934) shows a picture of "willow sets." Fishermen state, however, that large catches can be made in this way only is the "set" is visited at night. This might indicate that the shrimps are quiescent at night and leave the bushes during the day when they are more active.

Specimens taken in the course of this investigation were secured by means of wooden frame box-traps covered with fine copper screenwire, baited with fish and meat scraps, and placed in the Mississippi River below the town of Port Allen. The traps had cones of wire at the ends leading into small holes. The shrimp entered the traps through the holes and very few of them found their way out. The wire used in traps for this study captured small shrimp as well as large ones. The fact that the strip boxes used by the fishermen permit most animals under 40 mm. in total length to escape deserves special attention.

It was planned to run a series of traps from the surface to depths of thirty feet, but difficulty was encountered in maintaining anchors and buoys in the deeper water, and so this program could not be adhered to strictly. The traps were visited once a week.

The temperature and pH of the water were taken every week from November 12 to January 21, but the time was too short to show correlations of these factors with the data on shrimp. The temperature fell from 16°C. to 8°C. in this period. The pH ranged from 7.3 to 7.8 and the average of ten readings with the hydrogen electrode was 7.5+.

It was noted that when the river was on a rise and the turbidity was correspondingly higher few shrimps were taken in water over twenty feet deep, and these were sometimes dead. The fact that they were not buried in the mud suggests the possibility that high turbidity in deep water during flood or rise has an injurious effect, possibly by interfering with respiration. The turbidity at the surface on four such occasions, measured by the standard platinum wire method, was 2.9 cm., while the average of readings on six other week-ends when the river was not on a rise and the catch was normal was 7.2 cm.

Commercial shrimping is done in the warmer months, as the animals are scarce in the winter. It may be that *M. ohionis* migrates to deep water out of the range of traps during the winter, but the preceding observations cast doubt on this idea which is held by many fishermen. The shrimp may feed less in winter and thus not enter the traps readily, or the life cycle may be such that large anmials die off at this season. The reason, however, for the winter scarcity is unknown. Little experimental fishing was done during the warmer months; therefore the number of shrimp caught, 1614 in all, was smaller than would be desirable for some analyses.

The shrimp caught were sexed and measured in millimeters from the end of rostrum to the tip of the telson. For the plotting of curves these total length measurements were grouped in 5-mm. classes, following the method used by Weymouth, Lindner and Anderson (1933) in their study of the marine shrimp, *Penaeus setiferus*.

The largest male shrimp caught measured 68 mm.; the largest female measured 93 mm. As is shown clearly in the plotted graph (Fig. 1), derived from measurements of animals taken from December 17 to July 7, the females grow to a larger size than males. McCormick (1933) observed that the abdomen of ovigerous females is broader than that of the males.

Females were more numerous than males, as males comprised only 22.86 per cent of the 1150 shrimps taken from December 17 to July 7. During the time when the females were carrying eggs the males made up 9.11 per cent of the population; but before the egg bearing period th males made 31.80 per cent of the total. This indicates a definite change in the sex ratio at the egg-bearing period. A sex reversal, such as that claimed by Berkeley (1929) for the marine shrimp, *Pandalus danae*, could conceivably play a part in the sex ratio change, but this situation, with reference to *M. ohionis*, is considered to

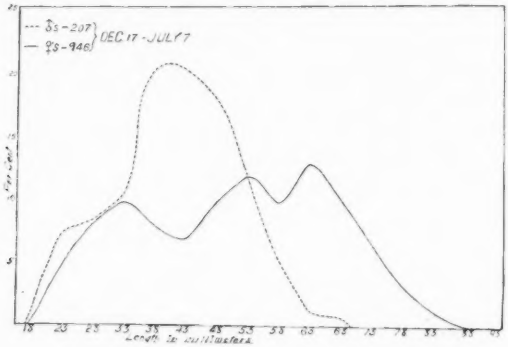

Fig. 1. Length-frequency curves showing sexual dimorphism.

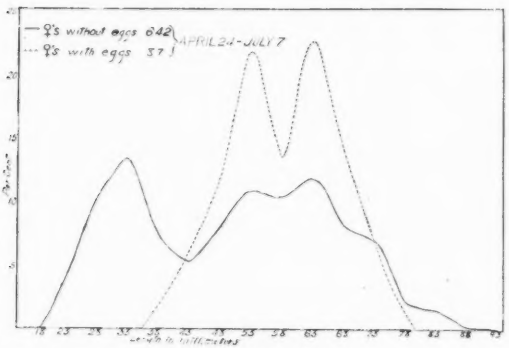

Fig. 2. Size distribution of eggless and egg-bearing females.

be improbable. Weymouth, Lindner and Anderson, *op. cit.*, have observed a change in the sex ratio of *Penaeus setiferus* associated with spawning.

The first egg-bearing females were taken on April 14 and females were still carrying eggs when the work was terminated on July 7. McCormick (1934) states that eggs in various stages of development are found on females

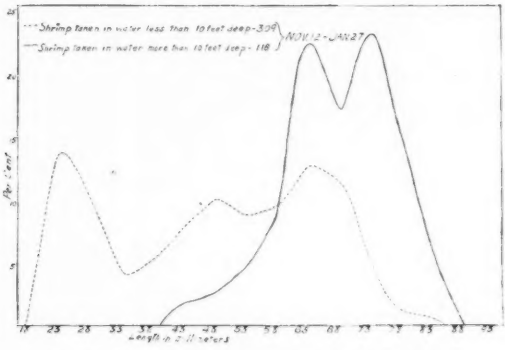
Shrimp taken in water less than 10 feet deep-309
Shrimp taken in water more than 10 feet deep-118
NOV 12 - JAN 27
Per Cent
Length in Millimeters

Fig. 3. Curves showing segregation of small shrimp in shallow water.

taken at the same time, and that females "in berry" were found at times to have a full complement of ovarian eggs. This would indicate that the spawning season is a protracted one.

During the part of this season observed only 13.39 per cent of the females caught were carrying eggs. The percentage, however, may give a false picture, for shrimp in this state may not enter traps as readily as others. Nevertheless, it shows that a number of adult females do not carry eggs during part, and possibly all, of the breeding season.

Ovigerous females ranged from 38 mm. to 76 mm. in length, while eggless females ranged from 23 mm. to 93 mm. Figure 2 is a length-frequency curve of these groups.

Small shrimp remain in shallow, sluggish water near the shore and do not venture into deep water as often as larger ones. This is shown by Figure 3.

Size frequency curves were plotted for each month, but the time was too short to warrant final conclusions, so the curves are not presented. They indicate, however, that from October to December the population was made up chiefly of animals from 60 to 80 mm. long. In January shrimp below 30 mm. in length predominated, their size increasing slowly to around 50 mm. in April. Thereafter the curves spread over a wider range as smaller animals came into the catch.

On the Louisiana coast the river shrimp moves into Barataria Bay in the

spring.[1] In 1932 *M. ohionis* were taken in the regular otter trawls used in investigations by the U. S. Bureau of Fisheries of the sea shrimp, *Penaeus setiferus*, from April 14 to June 23, and in 1933, from May 1 to June 3. Ninety-three river shrimp taken during these intervals ranged from 38 to 91 mm. in length and over 80 per cent of them were females carrying eggs. The shrimp were usually in the upper part of the bay, but on two occasions they were found more than half way down the bay, within four miles of the open Gulf.

During the spring the salinity of the bay falls because of the influx of a larger volume of fresh-water than comes at other seasons, and apparently the river shrimp come into the bay at this time every year. The species thus can, and probably has, spread from river to river by means of connecting bays. The bottom salinity at sixteen stations where *M. ohionis* was caught averaged 6.97 parts per thousand and ranged from 1.38 to 14.24 parts per thousand. The eggs on the shrimp appeared to be developing normally.

If undue pollution of the rivers does not arise, the present fishery for fresh-water shrimp will probably be maintained indefinitely, for the present method of trapping captures only the larger animals and leaves the smaller ones to carry on.

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1 In this connection, two specimens from bay waters near Port O'Conner, Texas, given me by Mr. Kenneth H. Mosher, of the U. S. Bureau of Fisheries, are of interest. They were identified by Dr. Waldo L. Schmitt, of the U. S. National Museum, as *Macrobrachium acanthurus* (Wiegmann), and suggest the possibility that other species of this genus may normally invade salt water.

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The Life-history and Habits of the Digger-wasp Ammobia ichneumonea (Linn.)

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Introduction

Though there are many taxonomic references to *Ammobia ichneumonea* in entomological literature, there exist only fragmentary reports of chance observations concerning its habits, and its life-history. Packard (1870) states that the wasp's nest consists of a single cell, provisioned with one grasshopper. The Peckhams (1898), who observed only one individual, confirm Packard's report. Davis (1911) and Hancock (1911) report two cells to the nest and several grasshoppers in each cell. Abbott (1931) finds three to four cells in each nest, with several grasshoppers or katydids in each cell. Hancock believes that the egg is placed on the last grasshopper stored in the cell, instead of the the first, the usual procedure when more than one prey is stored. Abbott states that the egg is laid on one of the victims, but he does not specify which one.

The following chapters are the result of three summers of observation and experimentation. The identifications of the prey and of the parasites were made by staff members of the Bureau of Entomology of the United States Department of Agriculture.

Nomenclature

Beginning with Linnaeus, the wasp has borne the following names. *Apis ichneumonea,* Linnaeus (1758); *Vespa jamaicensis,* Drury (1770); *Sphex ichneumonea,* Fabricius (1775); *Chlorion (Proterosphex) ichneumoneum* (Linn.), Fernald (1907); *Ammobia ichneumonea,* (Linn.), Rohwer (1911); *Chlorion (Ammobia) ichneumoneum,* (Linn.) Fernald (1931). The choice between the last two names depends upon whether Ammobia is regarded as a genus or a subgenus. In this work it is regarded as a genus. I am indebted to Miss Grace Sandhouse of the Bureau of Entomology of the United States Department of Agriculture for this information.

Description

Ammobia ichneumonea is a rather robust insect of medium size, the females measuring from 20 to 25 mm. in length, and the males from 16 to 23 mm. They are strikingly colored. The head, thorax and petiole and the bases of the legs are black, the abdomen is black and ferruginous and the legs are mainly ferruginous. The wings are nearly hyaline, though in some individuals they are quite fuliginous. A golden pubescence and golden or yellow hairs form a dense covering on the clypeus and frons of the head, and over

the greater part of the thorax, so that these parts gleam like burnished gold. It is this combination of gold and black and rich red-brown that has given rise to the popular name, Great Golden Digger. A complete and detailed description of the wasp is found in Fernald (1907).

Distribution

Ammobia ichneumonea has probably the widest distribution of any of the *Spheciae* in America. Fernald has seen "specimens from Maine, New Hampshire, Massachusetts, New York, Ontario, Wisconsin, Michigan, Illinois and Colorado on the north and from almost every state southward to Florida, Texas, New Mexico, northern and southern California, Utah and Nevada. I have also seen it from Mexico." Fox and Ducke report it from Brazil; Kohl and Cameron from Guatemala, Nicaragua, Costa Rica, Panama, Guiana, Venezuela, Cuba, Jamaica and Santo Domingo. The last lists, however, include the subspecies.

The wasps are never abundant in any one locality. Even if they are present in some numbers one year they may be scarce or absent the next year.

The Annual Cycle

In the vicinity of Woodstock College, Woodstock, Md., where these studies were made, the wasps appear about the middle of June. Individuals have been hatched from the cocoon of the previous year as early as June 9. The earliest nest building was observed on June 19. The season lasts well on into September, for the last nest observed was started on September 23. According to Fernald (1907) the wasp is a conspicuous visitor on the flowers of Sumac, Clematis, Asclepias, Mint, Ceanothus and Golden Rod.

There seems to be only one generation a season, though this point needs further investigation. A larva collected on June 29 spun its cocoon almost immediately and emerged as a wasp on July 15. Unfortunately, no other cocoons of a date earlier than August 1 were collected. The August cocoons did not hatch until the following spring.

Nesting Sites

An uncemented brick walk on the southeast corner of the main building of Woodstock College was the first site on which *Ammobia ichneumonea* was observed. The wasps tunneled down between the bricks and built their cells in the soil beneath. About ten nests were located here between June 25 and July 20. Another site was the south side of a small earthen mound which served as a base for a statue. From August 13 to September 21 twenty-six nests were built there, all but a few facing south, the others facing southwest. A third site was a low grassy slope also facing due south. This was not discovered until September 9, but between that date and September 23 eight nests were built there. One unusual location was on the north side of the building underneath a balcony where the sun would not reach the nests until late in the afternoon. Only three nests were built there. The first three

locations were occupied during two seasons, which might indicate that the same sites are used year after year. There seems to be a tendency on the part of the wasp to remain at the location she first chooses. Thus, one wasp, the first to appear on the brick-walk site on June 19, built four nests within a radius of three feet, remaining in all fifteen days on this site.

The Nest

The presence of a nest is indicated by a hole about a quarter of an inch in diameter with a leveled mound of soil in front of it, measuring about two or three inches in diameter.

The entrance tunnel descends at a sharp angle of about 85 degrees for a distance of five to seven inches. The tunnel opens into a chamber large enough for the wasp to turn around in. From this chamber, and beginning a little above the floor of the chamber, there radiate short tunnels, one or two inches in length. These terminate in an oval cell between one and a half and two inches in length and three-quarters of an inch in diameter. Two, three or four cells are thus connected with the central chamber. Usually these cells are all on the same level but occasionally one cell will be an inch or more below the level of the rest. These cells are built one at a time, and after being provisioned the short tunnel connecting them with the central chamber is completely blocked with soil before another cell is started. Table I shows the number of cells found in some of the nests, dug up to obtain material for studying the development of the larva. Nest No. 18 was a double-tiered nest. Four cells were connected with the central chamber, but another tunnel descended almost straight down from the central chamber for about two inches into another similar chamber, from which in turn radiated three tunnels ending in cells.

TABLE I

Number of cells found in nests.

Date	No. of nest	No. of cells	Stage of nest
August 17	9	2	Apparently completed
August 18	10	3	Apparently completed
August 18	11	2	Incomplete
August 19	13	2	Incomplete
August 19	14	1	Incomplete
August 22	18	7	Completed
August 22	19	6	Completed
August 23	15	1	Incomplete
August 23	16	1	Incomplete
August 23	17	3	Incomplete
Sept. 14	33	3	Incomplete
Sept. 16	34	2	

The cells are not built in any definite direction with relation to the entrance tunnel. In nine nests the contents of the cells made it possible to ascertain the order in which the cells were built.

In one nest, the first cell was built in a direct line with the entrance tunnel. In five nests the first cell was built from 30 to 170 degrees to the right of the tunnel. In three nests the first cell was built from 15 to 85 degrees to the left of the tunnel.

In the five nests, whose first cell had been built to the right of the tunnel, the remaining cells were built to the right of the first cell, in clockwise fashion, in two nests, and to the left, or counter-clockwise, in two others, and in the fifth nest, one cell was built to the right, and the other to the left of the first cell.

In the three nests, whose first cell had been built to the left of the tunnel, the remaining cells were built to the left of the first cell, or counter-clockwise in one nest, and to the right or clockwise, in the other two nests.

Digging the Nest

The wasp, flying very low, within a few inches of the ground, investigates the site. Every now and then she alights and examines a spot, or walks around looking the ground over very carefully. She tries the soil, here and there, apparently decides upon a spot and sets to work. But rarely is she satisfied with her first choice. At times she barely scratches the surface before she begins searching again. At other times she digs down one or two inches and then leaves for another location. She may leave the burrow open or she may close it carelessly.

The digging is done with the mandibles. The wasp bites the soil into small chunks. As these accumulate she sweeps them under and beyond her body by means of her well-fringed fore feet, of which the tarsi are curved or bent inward and upward thus forming a sort of rake. Bits of stone and other hard materials she pulls out and drags away. If a blade of grass obstructs her, she either tries to pull it out or very deliberately pushes it out of the way with her head. If unsuccessful in these efforts she attempts to cut the blade off.

As the circular hole deepens she carves the roof of the tunnel by lying on her side, now right, now left. The depth of the hole and the steepness of the incline soon make it impossible for the wasp to rake the soil out. Instead she gathers the soil by means of her folded fore-legs and pressing it to her thorax and the under surface of the head and neck, carries it out as neatly as if it were in a basket. She backs out of the nest with it, walking on four legs, for a distance of half an inch or more. With a sudden backward jerk she throws the soil behind her, between her legs. When the soil accumulates into a little mound the wasp stands on the mound, spreads out her legs and flattens herself, pushing the soil in all directions. Instead of this spreading movement she may kick the soil about. Large pellets she pushes to the edge of the mound with her head. During all this activity the wasp rarely unfolds her fore-legs, but walks about on their metatarsals.

Packard states that the wasp digs at the rate of one inch in five minutes and completes her nest in half an hour. The Peckhams state that their wasp took a little over four hours to finish her burrow. The time required depends

upon the character and compactness of the soil. If the soil is well packed it takes the wasp at least three hours of continuous work to dig the tunnel and the first cell. But rarely does a wasp work without interruptions. Either fatigued or hungry, she flies off at intervals and remains away for ten or more minutes. She may also discontinue work for the day, before the nest is completed. Usually in such cases the tunnel is filled carelessly, often only partially. The nest is then completed the next morning. Individuals have also been observed to desert their nest for an entire day, closing up one afternoon and not returning until two mornings later. There is a great difference in the industry of the individual wasps, some opening early and closing late, while others open late and close early. Tables 2 & 3 show the time of opening and closing of incomplete nests. The closing therefore, was not obligatory but merely indicates that the wasp was through for the day. The talbes also indicate that the most popular time for beginning the day's work was between nine and ten o'clock and the most popular time for quitting work was between one and two o'clock.

TABLE 2

Hour of day when work started and number of individuals for each hour.

Hour	No. of ind.
At 7:00 A.M.	2
Between 7:00 and 8:00 A.M.	6
Between 8:00 and 9:00 A.M.	7
Between 9:00 and 10:00 A.M.	13
Between 10:00 and 11:00 A.M.	5
Between 11:00 and 12:00 A.M.	1

TABLE 3

Hour of day when work stopped and number of individuals for each hour.

Hour	No. of ind.
At 9:30 A.M.	1
At 10:00 A.M.	1
At 11:30 A.M.	1
Between 12:00 and 1:00 P.M.	2
Between 1:00 and 2:00 P.M.	10
Between 2:00 and 3:00 P.M.	7
Between 3:00 and 4:00 P.M.	2
Between 4:00 and 5:00 P.M.	5
At 7:00 P.M.	2

Usually the observer can tell when the digging of the nest is completed and the cell is ready for occupancy. The wasp remains below longer than usual, sometimes several minutes and engages in a high-pitched musical buzz, which one feels inclined to interpret as joy over a task well done.

The pitch of this buzzing sound can be varied at will, and is apparently an expression of the mood of the wasp. When the work is progressing without any difficulties it is high-pitched and musical and somewhat sustained; when obstacles are met with or intruders in the form of ants and parasitic flies are encountered, it is low-pitched and rasping and sharply staccato. I agree with Latter (1913) that "it serves to warn off intruders on mischief bent." The buzz is produced by vibrating the wings. In the staccato form the wings are spread and raised at an angle of about sixty degrees and are then snapped sharply back onto the body.

Locality Study

After digging the nest and before going on the hunt, the wasp makes a careful study of the immediate vicinity of her nest, the locality study. The routine varies somewhat, but usually she walks about in front and around the nest, slowly and deliberately. She then takes wing and, flying low, she circles about the nest in ever-widening circles, often veering in toward the nest and then out again, until having circled her nest four or five times, she darts off for the neighboring fields, the habitat of the grasshoppers she uses for provisioning her nest. The actions of the wasp give every indication that she is trying to familiarize herself with the location of her nest.

How accurately does the wasp fix the location of her nest in her memory? She returns from the hunt either flying or walking. If she returns flying, she lands directly in front of her burrow, usually on the mound of dirt at the entrance of the tunnel, even though there are several other nests and mounds within the radius of one foot. Even when she returns walking through the tall grass and weeds surrounding her nest, she takes a direct route, ignoring all nests except her own. While wasps No. 15 and 17 were away, I dug up their nests, removed the contents of the cells and replaced the soil. The wasps on their return landed on the disturbed soil, an area about six inches in diameter. Since these wasps normally land within one or two inches of the entrance tunnel, their landing can be considered quite normal despite the changed condition of the soil. After prolonged search both of them began digging new holes, and as far as could be determined, at the places where the old entrances had been. Both nests, however, were abandoned the next day. In neither case had any cells been constructed.

Blades of grass placed in the tunnel so as to protrude for several inches, or a twig of a tree, one quarter of an inch in diameter, similarly placed, and closing the tunnel completely, will not confuse the wasp. These observations seem to indicate that the wasps can locate the entrances to their burrow by some means other than visual memory of the immediate gross surroundings of the entrance.

The following observation, however, does seem to indicate a dependence upon definite topographical features for a ready and immediate recognition of the entrance. A rain-storm during the night had washed away the mounds of soil at the entrances to the nests of the colony occupying the brick-walk site. Four nests were in operation here at the time. The mounds of soil

had been the only distinguishing features of these nests. In the morning, when the wasps came to begin operation, the absence of the mounds confused them. They arrived singly. Each wasp inspected the different nests, looking into the partially filled tunnels or occasionally entering one of them only to decide that it was not her nest. One of the wasps began cleaning out one of the tunnels, but after carrying out a few loads of soil somehow recognized her mistake and started her search again. Two wasps, both uncertain of their nests, threatened each other with vibrating wings and wide-open mandibles. It took each wasp at least ten minutes of trial and error to definitely locate her nest.

The Prey

Ammobia ichneumonea provisions her cells with a variety of grasshoppers. The species captured varies with the locality, the abundance and probably with the season. According to Packard (1870) she uses *Orchelimum vulgare* and *Conocephalus fasciatus (Orchelimum gracile)*. Davis (1911) has taken *Atlanticus dorsalis* from her nests in Georgia, and has seen her carrying *Neoconocephalus triops (Conocephalus triops)* on Long Island, N. Y. Hancock, observing the wasp at Lakeside, Michigan, has taken *Orchelimum vulgare, Orchelimum concinnum* var. *delicatum (Orchelimum delicatum)* and *Neoconocephalus attenuatus (Conocephalus attenuatus)*, both brown and green, from her nests. At Woodstock, during the first week of activity, which is the last week of June, a large dark grey, dappled, grasshopper, a wingless male, and a much larger, lighter colored female were brought in. Through loss of the specimens I was unable to have them identified, but I considered them members of the genus *Atlanticus*. These were succeeded on June 27 by immature specimens of the green grasshopper *Neoconocephalus attenuatus*, male and female, some of them light brown in color. It was only on August 17 that the first full-grown *Neoconocephalus* was found in a cell. On September 2, an immature individual of a different species, *Conocephalus attenuatus (Xiphidium attenuatum)* was found. About a week later mature specimens of this species were also brought in.

The reason for this change from immature to mature Neoconocephalus, and then to immature and finally mature Conocephalus may be the relative appearance and abundance of the species, and the greater ease with which immature specimens may be captured. But I think another factor is the size of the prey. The mature grasshoppers are quite large and heavy and the droning noise that heralds the approach of a wasp carrying a grasshopper indicates the effort it is costing her. Hancock determined that the male of the green meadow grasshopper weighs approximately seven grains, while the female weighs between ten and eleven grains. *Ammobia ichneumonea* weighs approximately five grains, half the weight of the female meadow grasshopper. It is reasonable to suppose that the wasp will select smaller and lighter grasshoppers if they are available. For the same reason she will select immature specimens. Table 4 shows that only 22 out of 86 grasshoppers found in the cells listed here were mature specimens. This opinion seems confirmed by the fact that, though *Orchelimum vulgare*, which is larger and heavier than *Cono-*

cephalus and *Neoconocephalus* is present at Woodstock, it was never used as prey. Yet the larvae of the wasp readily accepted and devoured artificially incapacitated individuals of *Orchelimum vulgare*. Abbot (1931) reports the use of katydids as prey, but he does not state the genus or species.

TABLE 4

Number, age and name of grasshoppers found in twenty-four cells.

Date	Number of cell	Number of prey	Age of prey		Name of prey	
			Immature	Mature	Neoconocephalus	Conocephalus
August 17	1	5	5		5	
August 17	2	4	4		4	
August 18	3	2	2		2	
August 18	4	6	6		6	
August 19	14	4	3	1	4	
August 19	15	3	3		3	
August 22	17	4	4		4	
August 22	18	3	3		3	
August 22	19	3	3		3	
August 22	20	3	3		3	
August 22	24	3	2	1	5	
August 22	25	4	4		4	
August 22	26	3	3		3	
August 22	27	4	4		4	
August 22	29	4	4		4	
August 23	36	3	1	2	3	
August 23	37	5	2	3	5	
August 23	38	4	1	3	4	
August 23	39	4	2	2	4	
August 28	48	5	1	4	5	
Sept. 2	51	2	1	1	1	1
Sept. 14	52	2	1	1	1	1
Sept. 16	55	3		3	3	
Sept. 18	57	3	2	1	1	2
Total		86	64	22		

The Capture of the Prey

No captures in the open have been observed, but by offering the grasshoppers to the wasp, while she was provisioning her nest, her method of capture could be followed quite readily. A specimen of *Neoconocephalus ensiger* was placed in a wide-mouthed bottle three and a half inches in diameter and five and three-quarter inches in height. The neck of the bottle was two inches in diameter and one and a quarter inches long. The grasshopper was on the bottom of the bottle. Wasp No. 21 had just brought in a grasshopper and while she was down in the burrow the bottle with the grasshopper was inverted over the entrance to the nest. The grasshopper remained upside down on the floor of the bottle. The wasp came up from below, but remained in the entrance and looked around. The presence of the bottle disturbed her and she backed down out of sight. Presently she came up again, looked intently at the neck of the bottle, came out of the tunnel. turned around and then entered it again. She came up once more, preened herself, walked up to the bottle, climbed the neck, and then as she found difficulty in climbing,

helped herself by means of her wings. She became excited and flew around rather wildly, occasionally climbing the glass. The third time she reached the roof of the inverted bottle she saw the grasshopper and darted at it, and alighted, her abdomen markedly curved, its tip pointed forward, on top of the grasshopper. Both fell to the ground, the wasp clinging to the grasshopper and landing uppermost. The grasshopper lay motionless; evidently it had been stung and paralyzed in the first lunge. The wasp then deliberately touched the tip of her abdomen to a point on the thorax between the first and second pairs of legs, and again between the second and third pairs of legs. Then she stood over the grasshopper and drawing her mandibles along the back of its neck and thorax, she straightened the slightly disarranged wings. Still straddling the grasshopper, she grasped it by the antennae with her mandibles and proceeded to drag her capture to her nest. The grasshopper had given no signs of recognizing the wasp as an enemy while she was flying about in the bottle.

Wasp No. 27 was down in her burrow stowing away a grasshopper she had just brought in. As she came up a grasshopper *(Neoconocephalus ensiger)* was placed about three inches in front of her. She saw it almost immediately and pounced upon it. This time it could clearly be seen that she attacks her prey by grasping it with the tarsi of her legs, at the same time manouvering it into a face to face position where she can reach its neck with the tip of her abdomen, presumably to sting it in the region of the suboesophageal ganglion, for the sting is directed upward and forward. This stab completely incapacitated the grasshopper. The wasp then rapidly applied the tip of her abdomen to the thorax twice apparently between the first and second, and between the second and third pairs of legs, somewhat to one side near the base of the legs, the sting being directed toward the midline. The wasp then straddled the grasshopper and grasping it at the base of the antennae dragged it to her nest. After she had stored her prey, the wasp was offered another Conocephalus. She followed the same procedure, stinging it once in the neck and twice in the thorax. This grasshopper was likewise stored.

Wasps No. 29, 34 and 35 followed this same procedure, one sting in the neck and two in the thorax. It would seem then that the usual procedure is to first paralyze the suboesophageal ganglion and then the thoracic ganglia. Fabre (1919) states that the grasshoppers are not stung in the suboesophageal ganglion for this would kill the animal. However, there is no doubt about the sting being inserted in the neck near the ganglion, even though the ganglion may not be pierced.

Staining to Determine Where Sting Entered

Even in these controlled experiments the wasp is so quick and furious in her attack, and so close to her prey, that it is often difficult to be sure where her sting strikes.

A 5 percent aqueous solution of acid fuchsin was decolorized by bubbling SO_2 through it. When fully decolorized drops of the solution were applied to the neck and thorax of the paralyzed grasshopper. After a short time minute red spots appeared on the neck and thorax where the wasp had applied

the tip of her abdomen. Immersing the whole grasshopper in the indicator resulted in a slight diffuse tinting of some other parts, but there was no mistaking the decided color at the presumed points of puncture.

Incomplete Paralysis

Three instances of incomplete paralysis came under my observation. In two instances there was quite a noticeable movement of the head and legs. In the third instance it looked as though the grasshopper would get away, as the wasp left it on the mound and descended to make her inspection. It could move all of its legs and even its wings, but it could not coördinate their movements. The wasp apparently saw nothing unusual in the movements of its prey, for she dragged it down into her nest. These instances indicate that the precision of the wasp in stinging her victims varies, for I have seen the grasshopper paralyzed completely by the first stab of the sting.

A paralyzed grasshopper taken from a wasp's cell at 3:00 P.M. and brought to the laboratory, began to stridulate at 7:15 P.M. and continued the performance, while I held it in the palm of my hand for fully a minute. After that it never performed again. This is the only instance of its kind that I have observed, although I have handled several hundred paralyzed grasshoppers.

Method of Bringing the Prey Home

The prey is usually captured some distance from the nest and the wasp has to drag it, or to fly with it. To drag it, the wasp mounts astride its back, much as a rider mounts a horse, grasps the base of the grasshopper's antennae, and then walks along in a rolling, floundering fashion. The legs of the grasshopper become entangled in every grassblade and other obstructions and make the wasp's work quite difficult. Consequently the wasp prefers to fly with her burden. In this case she mounts the grasshopper in the same manner, grasps the antennae with her mandibles and then hooks her legs around the wing cases and the body of her victim. She then rises into the air and flies home. It is quite a task to fly with the grasshoppers, for they are larger, and, as stated, often heavier than the wasp. In fact the wings move so rapidly that they produce a sonorous hum, like the drone of an airplane motor, which can be heard while the wasp is still some distance from the nest. It is for this reason that the wasp will, whenever possible, climb up some elevation from which to launch her flight. Any tree, shrub, or weed, or even a human being, conveniently at hand will be utilized. If her burden is especially heavy, she may have to repeat this manouver several times, before reaching home.

When unsuccessful in hunting, the wasp returns to her nest every fifteen or thirty minutes. She may merely alight and look about, though she usually enters and inspects the nest.

Storing the Prey

Arriving at her nest, either by flying or walking, the wasp drops the grasshopper on the mound of soil, about one inch from the entrance. From here

on the routine varies. The wasp may enter the tunnel directly, and go below, apparently to inspect the condition of the cell. She reäppears after five to fifteen seconds, coming up head foremost, reaches out, or walks out, grasps the grasshopper by the base of the antennae and backs down with it into the nest. Or, instead of going down immediately to inspect the nest, the wasp may first back into the tunnel until only her head protrudes and crouching there, scan the immediate neighborhood. Sometimes she backs down into the tunnel fully an inch and is then invisible except by looking directly into the tunnel, but, within a few seconds she moves forward to the entrance and looks around. If satisfied with her survey, she comes out, goes down head foremost, reäppears head foremost and then takes the prey down as described. This survey of the nest's vicinity is not without reason. Ants are searching the neighborhood for food and a paralyzed grasshopper would be a welcome find. Parasitic flies, who lay their eggs on the grasshopper, are a constant menace and are frequently seen about the nests. In her survey the wasp sights an ant approaching. She moves partially out of the tunnel and attempts to frighten the intruder by a wave of her antennae, and an angry buzz. If unsuccessful in this manouver, she lunges at the ant, and, if necessary, strikes at it with her mandibles. But she does this rather gingerly. I have seen her strike at an ant and then fly up and backwards for a foot or more, as though she meant to pick up the ant and drop it away from the tunnel. On one occasion I saw an ant attach itself to the grasshopper the wasp was dragging home. As the wasp dropped her burden at the entrance she noticed the ant. Instantly and repeatedly she struck at the ant with her mandibles, but seemed afraid to touch it. Finally, in a great hurry, she picked up the grasshopper with the ant still attached to it and flew off with it. Three minutes later the wasp returned empty-handed. It is quite likely that repeated experience with ants make the wasp cautious in attacking them. I have seen a wasp routed by ants while digging a new nest. She had penetrated one of the tunnels of an ant colony. I have also found practically completed nests deserted for the same reason.

Parasitic flies are disposed of much more quickly. The wasp darts at them boldly and drives them off.

Having disposed of any menace lurking in the neighborhood, the wasp returns to her crouching position in the entrance for a few seconds. She then comes out, goes down head foremost to inspect the condition of the cell.

Sometimes one inspection of the nest does not satisfy the wasp. She goes down, but instead of turning around in the nest and coming up head foremost she comes backing up, goes down again and once more comes backing up, and this she may repeat three or four times. But finally she goes down and turns around in the cell and comes up head foremost and takes the prey below, backing down.

The grasshoppers are placed in the cell, lying on their sides, with their heads toward the blind end. Though placed on top of one another, they are slightly staggered, the head of each succeeding victim lying on the thorax of its predecessor.

The Laying of the Egg

Packard (1870) and the Peckhams (1898) found only one grasshopper in the cell which they studied, and this carried an egg.

Hancock (1911) found only two cells containing an egg. Of the first he says "The top grasshopper, which would seem the last one taken into the burrow" carried the egg. Of the second he says that the egg was found on "one of the male coneheads and probably on the last grasshopper stored." He mentions that Packard and the Peckhams found the egg on the first grasshopper taken in, but he does not attempt to explain the discrepancy.

With the single exception of wasp No. 34, which laid two eggs, one on the first grasshopper taken in and one on the last, all eggs and young larvae, twenty-six in all, were found on the first grasshopper. It is possible that Hancock dug up the cells and then studied their contents, instead of examining them in situ, for in the latter case there is never any doubt as to which grasshopper was taken in first.

The egg is usually fastened on the ventral side of the thorax on the suture between the pro and the mesosternum, where the cuticle is membranous and more readily penetrated by the larva than would be the chitinized cuticle of the sclera. It is placed somewhat nearer to the left fore coxa and usually lies transversely across the body. Occasionally an egg has been found standing on end. And occasionally the egg has been found fastened to the membranous cuticle of the neck.

Closing of the Cell

During the day, while the wasps are hunting, the tunnel and the cell being provisioned at the time, are open to any intruder. When the wasp is about to discontinue work for the day, she scrapes only a small amount of soil into the tunnel, apparently closing only the entrance to the central chamber, so that usually there is no evidence of this closure from the surface. It is an easy task to open the nest for further provisioning the next morning.

When the provisioning of the cell with from 3 to 6 grasshoppers is completed, the wasp fills up the short tunnel connecting the cell with the central chamber, and thus effectively closes the cell. She obtains the soil for filling the tunnel in several ways. Occasionally she uses some of the soil of the mound outside the entrance. But the amount of soil she scrapes down is too small to complete the filling; and in many instances the wasp does not use any of the excavated soil. Instead she immediately sets about digging another cell and uses this excavated soil for the closing of the tunnel of the provisioned cell. The activities of wasp no. 20 show this clearly. After storing four victims, she remained below the surface for forty-five minutes, coming up only four times with a load of soil. She was evidently digging. After the forty-five minutes she came up regularly at short intervals, each time with a load of soil, and continued this for twenty-five minutes. She then flew off and quit work for the day. The next morning she resumed her digging and after 40 minutes completed the cell and went off to hunt. After she had stored one grasshopper I excavated the nest and found one closed cell

with four grasshoppers and one open cell with one victim. It is evident that during the forty-five minutes that the wasp remained below after storing four grasshoppers she was digging a new cell and instead of bringing the soil to the surface, she used it to fill the tunnel of the cell she had just finished provisioning, except for the four loads she brought to the surface during that time. Having completely closed the tunnel she now, for the next twenty-five minutes brought the soil she was excavating to the surface. She then stopped work for the day and completed the excavating of the new cell the next morning after forty minutes of work.

This routine, of opening one cell and closing another at the same time, being one of her normal reflexes, might explain why occasionally a wasp will bring soil to the surface only to throw it back again into the tunnel. She may be engaged in the excavating of a new cell and the closing of an old one, but she is doing it in a roundabout way.

Closing of the Nest

After provisioning from two to four or more cells, the wasp closes the nest permanently. Standing on the mound of soil with her back to the nest, the wasp throws the soil between her legs toward and into the tunnel. She then follows it down head first to pack it. After 15 to 30 seconds she comes up, scrapes or throws more soil into the burrow and descends head first with a grunt-like buzz. To vary the procedure she may go down backwards carrying the soil with her as she descends.

As the tunnel fills up it can be seen that Ammobia user her head to pound down the soil, much in the manner of a trip hammer, the rapid vibrations of the head being accompanied by a strenuous buzzing. Pebbles or hard clumps of soil are usually not used in the first stages of the filling and the wasp will frequently pick them up off the mound in her mandibles and remove them to the edge of the mound. However, in filling the last half-inch or more of the tunnel bulky material in the form of clumps of soil, small pebbles, bits of twigs and grass is added to the soil. Frequently the bulky material appears unsuited after being pounded in and is removed and cast aside. Since the mandibles maintain their grip, or at least continue to encircle the bulky material while it is being pounded, the subsequent removal of it would be interpreted by the Peckhams as evidence that it had been used as a tool.

In some cases the tunnel is completely filled level with the surrounding soil. If any of the excavated soil remains it is levelled and scattered so as to leave no evidence of it. The mouth of the tunnel is so artfully concealed by bits of twigs and grass and pebbles that it is impossible to locate it. In other instances as much as a quarter of an inch of the tunnel may remain unfilled, except for a few pieces of bulky material, and a small mound of excavated soil may be left untouched.

New Nests

New nests are started the same day the old ones are closed. Table 5 shows that they may be started at any time of the day, as early as 8:30 A.M.

and as late as 5:00 P.M. The selection of a new site often takes considerable time. I have seen wasps, starting a new nest in the afternoon, try out from three to five different locations, digging down from one to four inches, but finally postponing the selection until the next morning. This probably accounts for the fact that most new nests are started in the morning hours. If the new nest is started in the afternoon, the wasp apparently builds the first cell and then carelessly closes the nest for the night.

TABLE 5

Relation between the time of day and the starting of new nests.

Time of starting	Number of individuals
8:30 A.M.	1
10:00 A.M.	1
10:05 - 11:00 A.M.	6
1:00 P.M.	2
3:45 P.M.	1
4:00 P.M.	1
4:15 P.M.	1
5:00 P.M.	1

Hatching of the Egg

The eggs are between five and six millimeters in length and about one millimeter in width and are slightly bowed into a shallow crescent. They are pearly white in color and somewhat translucent.

As the development of the egg proceeds, its color changes to a light yellow and the somites and the lateral bands of the larva become visible through the thin egg shell. The incubation period is about forty-eight hours, though I have observed two doubtful cases of seventy-two hours. The reason for this uncertainty is the fact that it is quite difficult to determine the exact moment of hatching, because the larva begins to feed even before the egg-shell is ruptured. This is accomplished in the following manner. The head of the larva develops at the attached end of the egg. The larva pierces the shell at this point without, however, breaking the point of attachment and dislodging itself. It then attacks the membranous cuticula of the body wall of the grasshopper and pierces this, thus entering the body of the prey with its head, and begins feeding while still encased in the egg-shell. It is thus held in position by the still attached egg-shell.

The increase in the size of the larva due to the feeding results in a rupture of the egg shell on the dorsum of the larva, about one millimeter from the posterior end, in the vicinity of the fourth abdominal segment. This rupture is evidenced by the exudation of a small drop of fluid at the point of the rupture. A portion of the underlying somite slowly makes its way through this opening, which gradually widens into a slit. About half an hour later, the slit has extended forward about half-way and backwards to within about one-half of a millimeter from the posterior end, though it has worked down

the sides of the larva only about one-third of the way. The egg-shell thus forms a cradle for the young larva and still holds it in position on the grasshopper. During the next twenty-four hours the growing body of the larva bulges more and more out of the slit until its posterior end is completely liberated. The shell then slowly shrinks down onto the head of the larva and drops off. By this time the head of the larva is imbedded in the body of the grasshopper and there is no further danger of the larva being dislodged.

The Larva

The larva remains in this position and feeds uninterruptedly, its head and the anterior end of its body gradually disappearing within the thorax of its victim. The posterior half of its body always remains on the outside. Usually the larva remains on the first grasshopper until only the chitinous skeleton and the wings and legs remain, a period of at least four days. By this time the larva is about a half an inch in length and about an eighth of an inch in diameter, robust and capable of fending for itself. After finishing the first victim the larva withdraws its head, and because of the proximity of the next victim easily wriggles or lopes into position to attack it. The thorax of its victim being nearest at hand, the attack is usually made at this point, though individuals in the laboratory where the grasshoppers were not stacked as they are in the natural cell, have been observed to enter the body of the grasshopper through the neck, abdomen, or anus. Moreover, after entering at one point and feeding for a while, the larva may leave that part and enter at another point. Though it takes the larva four days to consume the first grasshopper, the succeeding victims are devoured very rapidly at the rate of one, or even two a day.

The extent to which the grasshoppers are devoured varies, and in general, depends on the number supplied. The larva of cell 49 experimentally supplied with only one, immature, wingless grasshopper, left no trace of it, devouring even the jumping legs. If, after cleaning out the last victim, the larva is still hungry, it will return to the formerly discarded remnants and devour them more or less completely.

Fabre (1921, p. 76) states that fresh food is essential for the wasp's larva, and that he knows of no exception. Larva No. 19 after a meal of two living grasshoppers, accepted and ate one that was dead but still fresh. Larva No. 27, after eating two live grasshoppers, ate two that had died, and which began to decay while it was feeding on them. Larva No. 40, collected as a three-quarters grown larva, accepted and partially devoured a dead but fresh victim before spinning its cocoon. Larva No. 20 ate in turn a live victim, a dead one, another live one, but refused a decaying one and spun its cocoon. While larva No. 25 was feeding on its first victim the remaining four grasshoppers in its cell died and two of them became discolored and gave off a foul odor; the larva, however, ate all four. All these larvae seemed none the worse for their experience and spun their cocoons in due time.

Honey, according to Fabre (1921, p. 273), is fatal to carnivorous larvae. Larva No. 18, after eating two grasshoppers was offered one whose neck, thorax and abdomen had been liberally smeared with honey, and whose thorax

and abdomen had likewise been injected with honey. The larvae ate the honey off the neck, then entered the thorax and remained there over an hour. It then entered the abdomen, and from there completely devoured the grasshopper, leaving only the legs and wings. The larva was then given a second honey-smeared victim. This it likewise attacked, but it ate only the abdomen and then spun its cocoon. An inspection of the cocoon a month and a half later showed that the larva was still alive.

Tests with Other Foods

After the larva of Cell 21 had eaten two of its grasshoppers, two large katydids, *Microcentrum rhombifolium (Microcentrum laurifolium)* were given to it. These were devoured completely, after which the larva spun its cocoon.

The larva of Cell 17 had just completed a meal of four grasshoppers. It accepted and ate three large katydids, and then spun its cocoon.

Both larvae had already eaten the food supplied by the wasp and in addition took an amount practically equal to that supplied by the mother.

The larva of Cell 27, in addition to its four grasshoppers ate one of two small crickets which I had killed by partially crushing them.

Length of the Larval Period

Table 6 shows that the length of the larval period varies; that the majority of the larvae took about eight days to complete their development; and that, as the season progressed, the larval period was gradually shortened to five days.

TABLE 6

Relation between the time of the season when the egg is laid and the length of the larval period.

Date egg collected	Length of larval period. in days
August 15	8
August 15	8
August 15	8
August 15	8
August 22	8
August 22	8
August 22	7
August 22	7
August 23	7
August 23	6
August 28	5
August 28	5
September 2	5

An excess of food may lengthen the larval period. The larvae of cell 17 and cell 21, mentioned above, were hatched on August 17, but they did not spin their cocoons until August 28, a period of eleven days. If the usual

larval period is eight days, it was here prolonged three days, by feeding the larvae several katydids after they had eaten their supply of grasshoppers.

A shortage of food, however, does not seem to shorten the larval period. The larva makes a more complete meal of the grasshoppers, eating everything, even the legs. The larva of cell 20 had only two grasshoppers, but it spent eight days in eating them.

The Cocoon

After eating its fill the larva spins a cocoon. The cocoon consists of six layers of silk with the usual inner chitinous shell. In size the cocoons varied from 3.3 cm. x 1.2 cm. for large larvae to 2.3 cm. x 0.9 cm. for small larvae. The cocoon never lies on the floor of the cell, but is cradled on a scaffolding of silk, which holds it in the center of the cell. The narrower, more tapering end, where the stercoral plug is formed, is always firmly fastened to the rear end of the cell, so that the young wasp in emerging from the cocoon is facing the exit of the cell.

The time it takes for spinning the cocoon varies from 36 to 48 hours.

In only one case was the voiding of the faeces and the formation of the stercoral plug observed. This took place four days after the larva began its cocoon. But in this case the cocoon had been opened to photograph its contents, and this may have hastened the voiding.

One larva, Cell 40, was removed from its vial where it had built the scaffold and had started on the bed of the cocoon. Placed in a clean vial with sand it tried for three days to get another start, but though its condition was identical with that in the first vial, it succeeded only in glueing a few pebbles together, and finally died.

Preservation of the Prey

It is commonly stated that the venom of the digger wasps has antiseptic properties, which preserve and keep fresh the flesh of the prey for weeks, (Fabre, 1919, p. 30; Metcalf and Flint, 1932), and even for months, (Wheeler, 1922). Usually no foul odor develops in the artificial, glass cells of the laboratory, though the larva be surrounded by the wet remains of partially consumed grasshoppers. Occasionally a foul odor, indicative of putrefaction does develop, especially if the grasshoppers die prematurely. In the latter case the larva apparently suffers no harm, since it continues feeding on the decaying remains and eventually spins its cocoon.

Occasionally a mold develops at the mouth or anus of the grasshopper. Repeatedly cells were discovered in the field, in which the grasshoppers were covered with a dense mat of mold, and here no trace of an egg or of a larva could be found.

To ascertain the effect of the poison on the longevity and preservation of the grasshoppers, a number of paralyzed grasshoppers were brought in from the field and placed individually within shell vials plugged with cotton. A number of non-paralyzed grasshoppers, caught in the field were kept under

similar conditions. Both were examined twice daily. Some of the results of these observations are given in Table 7.

TABLE 7

Relation between paralyzed and non-paralyzed grasshoppers as regards preservation and length of life in days.

Sex	Breathing	Response to stimuli	Passing of faeces	Remain fresh
Paralyzed grasshoppers				
male	8	14	11	17
female	10	13	11	15
female	7	12	10	14
female	8	14	10	17
Non-paralyzed grasshoppers				
male	4	6	4	8
male	4	6	4	8
male	5	7	5	9
female	6	8	5	11

The table shows that the paralyzed grasshoppers lived longer than the non-paralyzed animals. Their greater length of life is probably explained by their decreased metabolism, due to their inactivity. After death, as evidenced by failure to respond to mechanical stimulation, the carcases of both the paralyzed and the non-paralyzed animals showed discoloration within two or three days. This seems to indicate the absence of any special preserving quality in the poison of the wasp. Since the larval period lasts at most eight days, and in some instances was as short as five days, and since even non-paralized grasshoppers remain fresh for at least eight days, it would seem that the sole purpose of paralyzing the animals is to immobilize them, to prevent injury to the egg and the larva. It is possible, however, that the non-paralyzed grasshoppers would decay sooner in the moist environment of the wasp's nest.

Parasites

Intruders in the form of ants in search of food have already been mentioned. A velvet ant, *Dasymutilla sparsa* (Fox), (det. Grace Sandhouse) was seen entering one of the burrows, but she came out almost immediately. Another velvet ant was dug up with a cell containing a cocoon. Another, in this case *Dasymutilla sparsa* var. *segregata* Rohwer, (det. Grace Sandhouse), came out of a burrow at which the wasp was working. The wasp seemed surprised and peeved, for she ran after the intruder for a distance of about eight inches, snaping at it, but finally she let it go and resumed digging at her burrow.

True cases of parasitism were found repeatedly, and the following two species of Tachinid flies were recovered from parasitized cells both as larvae and pupae; *Metopia leucocephala* Rossi, (det. J. M. Aldrich) and *Senotainia trilineata* V. d. W. (det. C. T. Greene).

The usual result of the parasitic invasion is the death of the wasp larvae. Cell 50, however, contained a cocoon and two large and one small parasitic larvae apparently feeding on a few grasshopper remains.

Fabre (1919, p. 72) maintains that the parasitic flies never enter the nest of the wasp, but lie in wait until the wasp has left her prey on the mound to make an inspection of the nest, when they alight on the prey and deposit their eggs. I have witnessed this procedure once as stated previously. The wasp apparently recognized the eggs for instead of taking the grasshoppers down she hurriedly mounted and flew off with it, returning emptyhanded.

I have, however, seen Tachinids, among them *Metopia campestris* (Fall) and a larger Sarcophagid entering nests on several occasions. They remained below for from five to thirty seconds. *Metopia campestris* was never recovered from any of the cells, but a larger unidentified Sarcophagid was recovered. It is quite likely that the other, at that time unidentified, small Tachinids seen entering the nests, were *Metopia leucocephala* or *Senotainea trilineata*.

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Natural History of the Ambystomid Salamanders of Illinois

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The meager amount of information upon the life histories and natural histories of the ambystomid salamanders is scattered in many scientific journals. It is thought to be desirable to gather together here the results of the work which has been done on the six species found in Illinois. A key to the Illinois species follows, p. 000.

The family *Ambystomidae* is distributed over the entire United States, with twelve species represented. Of these twelve species, only six are found in Illinois. *Ambystoma jeffersonianum* (Green) ranges from Canada (Hudson's Bay) and the New England states, southward to Virginia, Illinois and Arkansas. *Ambystoma maculatum* (punctatum) (Shaw), the spotted salamander, ranges from Nova Scotia west to Wisconsin and southward to Georgia and Texas. *Ambystoma texanum* (microstomum) (Matthes), is known from Ohio and Illinois eastward to South Carolina and southward to Texas. *Ambystoma opacum* (Gravenhorst), the marbled salamander, has been reported from Massachusetts to Florida, west to Louisiana and Texas, and the Mississippi basin north to Arkansas, Missouri, Indiana and Illinois. *Ambystoma talpoideum* (Holbrook), the mole salamander, ranges from the South Atlantic and Gulf states, Louisiana to Illinois (extreme southern part only). *Ambystoma tigrinum* (Green), the tiger salamander, is widely distributed over almost all the United Sates, east of the Cascade range and Sierra Nevada, and extending southward over the northern portion of the Mexican plateau.

Ambystoma opacum

The Marbled Salamander, *Ambystoma opacum,* is one of the commonest species of *Ambystoma* in southern Illinois. In 1885 the Reverend Charles Mann excited the attention of herpetologists when he discovered that this species differs from all others in its habit of usually laying its eggs on land. The eggs of *A. opacum* have been collected during the fall months. Mann (1855) found eggs at Gloucester, Va., in November and December. McAtee (1907) states that this species is found with eggs in September and October in Monroe county, Indiana. In southern Illinois the laying of eggs is in October and November.

The eggs are laid under leaf mold, sphagnum, and other cover which will be covered during the heavy winter rains. These situations are usually in what are known as swamp forests. Dry upland areas are not suitable for the breeding activity of this species. Both sexes migrate to suitable breeding grounds about the first of October. *A opacum* does not like bodies of water

but prefers merely moist situations and will die if kept in the water and denied the chance for atmospheric respiration. The species never deposits its eggs in the water in nature and the female leaves the nest as soon as water nears it. The egg-laying site varies from year to year, influenced by the degree of moisture in the soil. The male becomes sexually active earlier than the female. After the adults are at the breeding ground the male excites a group to sexual activity by engaging in a series of rubbing movements which are exactly the same whether directed toward male or female. It is quite probable that the odor of the female excites the male to the production of a spermatophore. The behavior of the male induces the female to follow him and this brings the female into the right position for picking up the spermatophore. The female, however, may find and cover any spermatophore after she has been excited. The spermatophore of *Ambystoma opacum* has a distinctive form, its head being roughly quadrangular. The spermatozoa are held together by pelvic gland secretion and are frequently directed outward. The stalk of the spermatophore is formed by the mucous secretion of the cloacal glands and a supporting framework of eosinophilic secretion produced by glands lying on either side of the pelvic gland.

The female lays 75 to 232 eggs, with 150 for an average. The egg has four capsules and is capable of great desiccation without destruction. Eggs found in nature will absorb approximately their own weight of water within 24 hours when immersed. After laying, the female remains with the eggs for a period of a few weeks and may or may not return to them once she has left. She does not forage for food during the early part of the brooding period but after brooding for about a month she deserts the eggs, leaving them exposed and liable to being eaten by salamanders, insects, or other enemies.

The eggs will hatch on land as well as in the water; moisture, however, facilitates development. Eggs which have been desiccated do not hatch so quickly as swollen eggs when immersed in water. Unhatched larvae may winter over on land if the winter is very dry. Noble (1933) collected eggs containing such larvae in the field March 14. He also kept other eggs, in which there were living larvae, on ice for more than a year.

The terrestrial stage in the life history of *Ambystoma opacum* is an adaptation permitting the specieis to compete successfully in the same region with other species.

Lantz (1930) in studying the courtship of this species, found that courting males pursue other males, as well as females, and this results in an increase in general excitement throughout the group. It seems to have a mutually stimulating effect and brings more males into courtship at one time than would otherwise occur. Noble and Brady (1933) made a record of courtship as follows:

> The female first moves away from the spermatophore which the male has produced, although she has been following him for some time. She later moves back to cover it and shows definite undulations of the base of the tail, less intense than the tail wag of the male. A male is now following a female and is rubbing her with his chin. The

male wags his tail while following female and rubbing her. The male stops female by throwing tail across her path. The male is now astride female and rubs her with chin. Female slides back and follows male with nose near cloaca. Pair separates. Two spermatophores found on floor. Pair in full waltz. Male crawls over female and rubs her cloaca. Female is now following male. He undulates his tail base and produces a spermatophore. the female misses it and noses about on the ground 5 centimeters from the spermatophore. She finds it and moves first head, then body, and finally cloaca over it. The female undulates her pelvic region. Male still active and turns to female. The male thrusts his head under female's cloaca and raises her from floor. Female follows male but no spermatophore is produced. Male now follows female, his tail undulating. A spermatophore is produced but the female turns toward male and the pair waltz. Both undulate their tails. Male plainly seen to produce a spermatophore. The female in waltz position stops, moves away from spermatophore. She turns and moves over spermatophore and secures it while undulating tail base.

Ambystoma tigrinum

In this, the Tiger Salamander, the "Liebesspiel" is similar in many respects to that of *Ambystoma maculatum* and *Ambystoma opacum* and in some ways to that of *Ambystoma jeffersonianum*. This gives more support to Noble's idea that courtship behavior is essentially the same among related species and has phylogenetic significance.

The courtship begins by the male nosing other individuals, indiscriminate of sex, and was permitted by both males and females. The male would in most cases butt the female with his snout in the side or midventral region and often swim around holding the female balanced on his head. Later the male would thrust his snout into the side of the female and then work forward to her head and back to her cloaca. Sometimes the male went directly to the cloaca. In order to have a clear picture of the courtship it seems feasible to cite an original record of the courtship as given by Kumpf (1934):

At 11:17 the male was nosing the female vigorously. Begins at side, works to head and then to cloaca. Raises her high in the water. He comes to a clear space on the tank floor and leaves her to walk ahead. She follows with snout at his cloaca. He takes a step, then she, then he and then she. With tail at right angles to his body and waving, and his swollen cloaca being rubbed on the bottom of the tank, he drops a spermatophore. Female's snout is closely applied in the angle between his left hind leg and tail during this time. However, she is distracted by the approach of another male and goes off without noticing the spermatophore. At 1:36 two males are nosing a female, one butting especially in the cloacal region. She begins to follow him. At 1:37 he deposits a spermatophore and she continues to follow, snout close to his vent. With all feet off the bottom she settles on the spermatophore and removes its head. Male and female now in tandem position as he extrudes another spermatophore. Both have all feet off the bottom and their bodies are quivering. Their tails are raised at right angles to the bodies and are waving back and forth.

The striking position assumed by the female is specific for this species and the female never removed more than the head of the spermatophore. The number of spermatophores deposited is small and deposition is not necessarily controlled by the presence of females nor preceding courtship activities.

Blanchard (1932) did some work on the length of life of the Tiger Salamanders. A cluster of eggs allowed to hatch in the laboratory in the spring of 1920. In June only a single larval salamander, the largest, remained,

having preyed upon the smaller individuals. Early in August the gills disappeared and he took to land. He lived in an aquarium 3 feet square, for 11 years. Food was entirely earthworms and raw beef. At 3 years he was more than 10 inches long. In November, 1923 he was 10¼ inches and in October he was 10½ inches in length. Apparently this salamander was not affected by changes of season. In 1924 an adult female was put in the cage and has been there ever since. The female was brought into the laboratory in March 1924, and she laid eggs a few days later. Although the two remained together thereafter, there was no evidence of breeding and no eggs were laid. In July, 1931 the male, which had been kept for eleven years, died. He had been ill for several months, his body being much bloated while his limbs and tail became more and more skinny. His length at death was 9¾ inches. The female, 9 inches long in October, 1931, is still in good condition, with a record of at least 7 years of adult life.

Major S. S. Flower has recently reported that in the London Zoological Garden from 1866 onwards, there are many records of axolotls living 4, 5, and 6 years, with only one record of 9 years, 4 months, and 20 days. He mentioned a "white axolotl" as having lived 25 years in the Covent Garden Market. The larval phases can hardly be compared directly with those detailed above.

On March 19, 1935, the author collected 32 egg masses of *Ambystoma texanum* and *A. tigrinum*. Four days later, from these masses were hatched 426 individuals having an average length of 13 millimeters. On May 8 one *Ambystoma tigrinum* remained, having eaten 425 larval salamanders and an undetermined number of large *Daphnia*, and is now 83 millimeters in length.

Hay (1891) in speaking of this species remarks:

> In Indiana this species appears to pass the winter hiding about the margins of ponds, or in some cases, away from the water, under logs and such places.

Ambystoma punctatum

In early spring this species migrates from winter quarters to suitable breeding places—swamps, temporary ponds, and pools. The migration is always at night and is quite clear. The adults are found in the early spring in the ravines, but never the eggs. A little later the spermatophores and eggs are found in the ditches, swamps, and ponds. In central New York the migration appears as follows, as observed by Wright (1909):

1900, April 6	1904, April 1
1901, April 13	1905, April 1
1902, March 25	1906, March 28
1903, March 13	1907, March 24

These records were made for more than 20 individuals, which were found to be in groups of two each and which proved to be male and female. The normal effecive temperature of migration seems to be 50° F.

Wright and Allan (1909) have described the courtship of this species. The male shows no excitement, until, upon coming in contact with the female,

he becomes very restless, and "noses" her in a definite manner. It seems to be the object of the male to bring the top of the head in contact with the vent of the female. The throat region of the female seemed to be preferred, although he often began in the cloacal region or even at the tip of the tail and rubbed the dorsolateral part of the head along her whole ventral side. After each performance of this kind, the male swam away and grasped one of the sticks with its hind legs, bringing the cloaca close to the stem. The tail quivered for a moment and, with an arching of the region just caudal of the cloaca, the vent was lifted from the spermatophore. Then, he immediately returned to the female and began again the "nosing" process. The time consumed in depositing a spermatophore varied from 3 to 16 seconds, the periods for 13 consecutive depositions being: 5, 3, 6, 10, 13, 12, 7, 11, 12, 16, 11, 10, 10 seconds, respectively. In this way 22 spermatophores were deposited in 45 minutes.

Most of this time the female remained quiet. Three times, however, she slowly moved over a spermatophore until the vent rested upon it. Then the hind legs closed about it. In this position the female remained, each time, for 10 to 15 seconds and apparently made no effort to take any portion of the spermatophore into her cloaca. It seemed more like a simple passage of the spermatozoa from the spermatophore into the cloaca of the female.

Evidently the female must be present at the time the spermatophores are deposited and in this we find the explanation for the delay in deposition of spermatophores after the species has first appeared from hibernation. The males begin the migration but no spermatophores are deposited until the arrival of the females. With the arrival of the females and the ensuing courtship, the spermatophores are deposited. They occur in groups numbering from two to 125, covering an area of one-half foot to 3 feet square. The usual number in a group is between 30 and 50.

After the spermatophores are deposited, an interval elapses before the first eggs are recorded. This interval varies from a few hours to seven days. Egg-laying generally begins about the first of April, and may extend over a month or more. The egg complement varies from 130 to 225, which may be deposited in one to 10 bunches. At least 30 minutes are usually consumed in depositing a normal bunch of eggs.

Ambystoma jeffersonianum

Mohr (1931) described the essential points of the "Liebesspiel," while Kumpf and Yeaton (1932) studied in detail the activities of mating individuals. In starting the courtship the male climbs astride a female and embraces her with his forelimbs just behind her head. After two minutes in this position he clasps her around her hind legs with his head over her tail. He leaves her after a minute and stalks ahead but returns immediately to embrace her again, this time behind the forelegs. Together they swim around, the male's body undulating all the time. After a time the male leaves the female's back and proceeds ahead of her. His whole body is undulating and his tail is raised and waving while at the same time he

appears to be rubbing his cloacal region over the bottom. Then he embraces the female again and they swim around and settle to the bottom. Then the male moves slightly ahead with wriggling body and rapidly waving tail. The female's snout is closely applied to the male's cloaca. The male deposits spermatophores as the female follows. First her chin and then her body passes over the spermatophore and her cloaca settles down upon it. Her body shows slight undulations in pelvic region and the spermatophore is picked up in about one minute. Actual breeding has been found in this species only between March 31 and April 10.

Ambystoma texanum

Very little is known of the courtship or natural history of *Ambystoma texanum*. Cahn (1930) reported the finding and hatching of a set of albino eggs of this species. The courtship is probably similar to the other spring breeders found in this group.

Ambystoma talpoideum

Ambystoma talpoideum is a southern species which is found in extreme southern Illinois and nothing is known of this species except that it is seldom seen at any other time than the breeding season. It is not a common species in this state.

Natural History

Some of the color patterns of the ambystomids may be concealing, functioning by attracting the attention to them and diverting it from the outline of the animal. Some species *(maculatum* and *opacum)* are brightly marked, while others, which seem to have the same habits *(jeffersonianum* and *texanum)* lack the bright spots. Also, *Ambystoma tigrinum* differs in both brightness and size of the markings in specimens from different parts of the continent. With this evidence, it seems untenable to suppose that these patterns are protective devices.

The most conspicuous sense organs of the skin are the lateral-line organs. These represent an inheritance from the fishes in which the same rows may be readily identified. Dye (1921) found that these respond (as in fishes), to vibrations of low frequency in an aquatic medium. The lateral-line organs are present in larvae of all *Ambystoma,* but show various stages of degeneration in the adults.

In very young *Ambystoma* larvae, the skin darkens in the light and pales in the dark. With increasing age in the larvae, and hence with increasing function of the eyes, the reverse change in coloration occurs on exposure to light on an indifferent background. Blinded larvae of this age react as young larvae. Salamander larvae reared in aquaria with dark bottoms develop a dark coloration, because their eyes, like those of most vertebrates capable of color change, bring about an expansion of the melanophores. The impulses originate in the darkened retinae and are so strong that they overcome the tendency of the darkened chromatophores in the skin to contract.

The problem of the causes of migration has two different aspects: first, the development of a sensitivity toward certain external stimuli; and second, the nature of the directing mechanism of migration activated by this change. The first process is primarily controlled in Amphibia by the seasonal hypertrophy of the gonads, which in turn are under hormonal control, especially by the anterior pituitary gland. Sexually immature individuals do not take part in the chief migrations. The final releasing factor of the migratory impulse is a climatic change. This may be a temperature change, a sudden increase of humidity or perhaps heavy spring rains initiate the migration.

A comparison may be made between the migration of the young and of adult *Ambystoma*. During metamorphosis there is a great increase in metabolism and a need for oxygen. It would seem to be primarily this factor which drives the metamorphosing individual to land. It is known that the metabolism of adult ambystomids changes during the breeding season, but no marked drying of the skin or other bodily change has been noticed which would account for the migration of the adults in the reverse direction.

The brooding instinct seems to have fully formed in many groups of the Amphibia. Most species of Ambystoma abandon their eggs in the water, but *A. opacum* deposits its eggs on land in the fall and curls around them. It has been shown, however, that *A. opacum* does not return to its eggs when disturbed. Therefore, the bond between parents and eggs is not great in this species, and the brooding habit may have resulted merely from exhaustion of the female after egg laying.

Ambystoma have few methods of defending themselves from their enemies. As a group they are relatively immobile. Their habit of maintaining a fixed posture between movements results in their frequently being overlooked by possible enemies. Diller (1907) found an 8-inch Ambystoma with a grip on a 2-foot garter snake, and it was apparent that the salamander was having the better of the struggle.

FIELD KEY TO THE AMBYSTOMIDS OF ILLINOIS

I. Costal grooves 10 to 12.

A. Two distinct tubercles on soles.

1. Costal grooves 10 ---------- *A. talpoideum*
2. Costal grooves 12 ---------- *A. tigrinum*

B. One or no tubercles on sole.

1. Costal grooves 11.

a. Back with series of round yellow spots. ---------- *A. maculatum*

b. Back with about 14 silver, transverse bars. ---------- *A. opacum*

2. Costal grooves 10.

a. Faintly spotted or unspotted. ---------- *A. jeffersonianum*

II. Costal grooves 14. ---------- *A. texanum*

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ILLINOIS NATURAL HISTORY SURVEY,
URBANA, ILL.

Some Habits of Southern Fur-Bearers as Indicated by Trapping

Lee E. Yeager

Trapping may be a gory activity, but as it does exist in nearly every county or parish in the country I can see no reason why this source of scientific information should not be used whenever practical. I am chiefly interested in the natural history side of trapping, and I am strongly opposed to unnecessary cruelty that is sometimes associated with it.

From 1921 to 1925, inclusive, I ran an extensive line of steel traps on Crooked creek and 3 small, closely-grouped tributaries, in Webster county, Mississippi. Each year the same area, under almost identical conditions, was covered. All seasons began on November 15 and ended on January 1. Traps used were no. 1½ and no. 2 Victor, both sizes being of the long spring type; and they were visited daily, as early in the morning as possible.

Trapping was primarily for the purpose of taking opossum, mink and raccoon furs for revenue, but concurrently with all catches careful records were kept of the species, sex, location and type of set; activities, as near as could be determined, while in the trap; condition (drowned, defensive, feigning death, etc.) when removed from the trap; and bait, if any, used in capture. From these records it seems possible to interpret some of the habits of the above mammals before capture, and also their reaction to extreme alarm, such as being taken in traps.

The trapline covered about one mile of stream bottoms which were heavily timbered with oak, red gum, beech, maple and hickory. In general, the line followed the streams, except where the writer cut across the low, oak-pine hills in going from one stream to another. Many of the oaks, gums and beeches were old and defective, but at various places some cutting of the better trees had occurred. For the most part the stream banks were masked by a heavy growth of bushes, vines and cane or bamboo, *Arundinaria gigantea* (Walt.) Chapm. The entire area trapped was generally well provided with den trees and logs and with suitable sites for bank holes.

Relatively few fur-bearers other than opossums, minks and racoons were found in the vicinity. A considerable number of muskrats occurred on the parts of the streams running through cornfields, but skunks, civets, weasels and foxes, both red and gray, were scarce. Other mammals such as cottontail and marsh rabbits, gray and fox squirrels, and deer mice and meadow mice were common to abundant; bats, shrews and moles were common. Songbirds, crows, hawks and owls were also common. The bobwhite quail occurred in numbers around the edges of the fields, and was the only upland game bird found in the locality. Minnows, suckers, sunfish and catfish were plentiful in the larger streams, and frogs were abundant in all suitable habitats.

Two general sets, "bait" and "blind," in about equal numbers, were used in trapping. Traps were kept in good working condition at all times except during floods, which averaged not more than one per season. As these seldom lasted more than a day and night, and as traps were seldom frozen down for more than 2 or 3 days during the winter, the trapper could depend on an average of about 40 satisfactory nights of trapping weather during the 45-day season. The catch of fur-bearers for each of the 5 years is given in Table 1:

TABLE 1

The Annual Catch of Furs on Crooked Creek, Mississippi, 1921-1925

Year	Opossum		Mink		Raccoon		Red Fox		Weasel		Total		M. & F.
	No. & Sex		No. & Sex		No. & Sex		No. & Sex		No. & Sex		No. & Sex		
	M	F	M	F	M	F	M	F	M	F	M	F	
1921	15	14	5	6	6	4	0	0	0	0	26	24	50
1922	13	14	7	5	3	5	0	0	0	0	23	24	47
1923	14	17	5	5	5	4	0	0	0	0	24	26	50
1924	10	16	4	6	3	6	1	0	0	0	18	28	46
1925	13	16	4	7	4	5	0	0	1	0	22	28	50
Totals	65	77	25	29	21	24	1	0	1	0	113	130	243

Bait and blind sets were each divided into two types: water sets and sets on dry land. Of the total catch of 243 animals, baited traps accounted for 71.6 percent and unbaited (blind) traps for 28.4 percent; animals taken in traps set on dry land amounted to 52.7 percent of the total catch, and animals taken in water sets amounted to 47.3 percent of the total catch. These data are shown in Tables 2 and 3.

TABLE 2

Habitat Capture of Fur-bearers Trapped on Crooked Creek, 1921-1925

Habitat (location of traps)	Opossum		Mink		Raccoon		Red Fox		Weasel		Total		M.&F.
	No. & Sex		No. & Sex		No. & Sex		No. & Sex		No. & Sex		No. & Sex		
	M	F	M	F	M	F	M	F	M	F	M	F	
Dry land:													
Bait	44	46	2	3	3	3	1	0	1	0	51	52	103
Blind	4	7	2	1	6	5	0	0	0	0	12	13	25
Water:													
Bait	11	18	9	14	5	14	0	0	0	0	25	46	71
Blind	6	6	12	11	7	2	0	0	0	0	25	19	44
Totals	65	77	25	29	21	24	1	0	1	0	113	130	243

From Table 2, the following table showing the percent of fur-bearers trapped in bait and blind sets, each used in approximately equal numbers, is compiled:

TABLE 3

The Percent of Fur-bearers Trapped in Bait and Blind Sets on Crooked Creek, 1921-1925*

Opossum				Mink				Raccoon				Red Fox				Weasel			
Bait		Blind		Bait		Blind		Bait		Blind		Bait		Blind		Bait		Blind	
M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
39	45	7	9	20	32	26	22	18	38	29	15	100	0	0	0	100	0	0	0
84		16		52		48		56		44		100		0		100		0	
100				100				100				100				100			

* All percentage calculations to the nearest whole number.

To most readers, Tables 2 and 3 hardly need discussion. The number of opossums taken in bait sets indicates that this species is readily attracted by food; and the small number taken in blind set indicates that travel is more rambling and less restricted to given habitats than in minks and raccoons. Obviously, mink and racoon were not as strongly attracted to food baits as opossums, and their habits of travel are such that an experienced trapper may place traps in their exact routes. The single fox and weasel taken give, of course, no indication of the habits of travel. Both were lured by fresh rabbit flesh.

The fur-bearers taken in bait sets during the 5-year period were attracted by a number of natural foods, as given in Table 4. Fish, rats, mice, beef or the flesh of other domestic animals were never used, nor was artificial scent used at any time. It must be pointed out that no quantitative significance can be given these data as rabbit was used in probably three-fourths of the bait sets. The table is simply presented as a record.

TABLE 4

Food Baits Used in Trapping Fur-bearers on Crooked Creek, 1921-1925

	Opossum		Mink		Raccoon		Red Fox		Weasel	
Food	M	F	M	F	M	F	M	F	M	F
Rabbit	44	48	6	10	3	9	1	0	1	0
Squirrel	3	5	3	2	1	4	0	0	0	0
Chicken	4	6	1	1	2	1	0	0	0	0
Duck heads	0	0	1	1	0	1	0	0	0	0
Crow	1	1	0	0	1	0	0	0	0	0
Blackbirds	2	2	0	1	0	1	0	0	0	0
Sparrowhawks	1	0	0	2	0	0	0	0	0	0
Meadowlarks	0	1	0	0	1	0	0	0	0	0
Flickers	0	1	0	0	0	1	0	0	0	0
Totals	55	64	11	17	8	17	1	0	1	0

Dry land sets were usually made near trails, dens, and points likely to be visited by fur-bearers, such as brush patches, windfalls and fence rows. These sets were of both the bait and blind type, though the latter were placed chiefly on logs and in paths known or likely to be used by the animals. In

water, bait sets were made at the bases of trees growing at the stream edge, in stumps, holes or hollow logs, or in front of stakes especially driven for the purpose. Blind sets in or near water were made most frequently on logs, between stumps or logs and the stream bank, and sometimes in bank holes and hollow logs.

Many individuals were trapped on logs, and the log-walking proclivities of the 3 important species are indicated in the table below. These data deal only with fur-bearers taken in blind sets, which in all cases were unbaited traps.

TABLE 5

Log-walking Habit in Fur-bearers Trapped on Crooked Creek, 1921-1925*

Relation to Capture	Opossum		Mink		Raccoon		Red Fox		Weasel	
	M	F	M	F	M	F	M	F	M	F
Total catch in blind sets ____	10	13	14	12	13	7	0	0	0	0
Number taken in log sets____	4	3	6	3	11	4	0	0	0	0
Percent of total blind catch as made on logs, by sexes	17	13	23	12	55	20	0	0	0	0
Percent of total catch as made on logs, males and females	30		35		75		0		0	

* All percentage calculations to nearest whole number.

The above tabulation does not represent every animal trapped on logs as some of these sets were baited. In evaluating the log-walking habit these baited sets are thrown out as it is almost certain that some of the fur-bearers were attracted by the bait. On the other hand, if none of the log sets had been baited it is probable that the number captured on logs would have been larger, and a somewhat more accurate evaluation of log-walking obtained. It should be explained that logs were abundant and of every local size and degree of decay, both in and along the streams and on the higher timbered areas.

In water sets, a special effort was made to drown as many animals as possible in order to reduce the loss from "wring-offs" and escapes. Thus, traps were staked or anchored in deep water. The usual method of doing this was merely by stretching the 18- or 20-inch chain its full length toward the center of the stream or a pool and staking, but it was necessary at times to lengthen the chain with common baling wire. In numerous cases a pronged stake was driven a few inches beyond or to one side of the anchor stake, the function of this device being to engage the chain and thereby increase the difficulty of the animal in returning to shallow water. The sliding-pole or wire, though known to be effective, was little used.

The percentage of animals drowning in their attempts to escape may serve as a reaction index to extreme alarm. Minks and opossums showed a much higher drowning percent than raccoons, but the reason for drowning is believed to be different. The high figure for mink drowning indicates that these animals attempted to escape by deliberately, or perhaps instinctively,

diving into deep water, where the weight of the trap helped to pull such individuals below the surface. Opossums, after being taken in water sets, probably entered this medium more through lack of agility and strength to keep out of it than through any deliberative or instinctive effort at preservation. Although raccoons frequent water and enter it rapidly, it appears that they avoid this medium after being taken in traps. Comparatively great size and strength undoubtedly enabled a larger percent of the raccoons trapped in water to regain their footing after taking to water than in the case with minks and opossums. It was found that raccoons drowned most readily when trapped in muck covered by a few inches of water, where insecure footing and resultant exhaustion were significant contributory causes. Minks and opossums drowned even more readily than raccoons in muck sets.

The percentage of animals drowning is shown in the table below, this calculation being based on the premise that 75 percent (known to be a close estimate) of the water sets made were in or near water deep enough to drown the catch.

TABLE 6

Drowning of Fur-bearers Trapped on Crooked Creek, 1921-1925*

Relation to Capture	Opossum	Mink	Raccoon	Red Fox	Weasel
No. animals taken in water sets	41	46	28	0	0
No. of possible drowning sets	31	35	21	0	0
No. animals drowned in sets	23	28	7	0	0
Percent of each species drowned	74	80	33	0	0

* All percentages calculated to nearest whole number.

In making bait sets on dry land, rabbit or other food was usually stapled to a tree or stake 12 to 15 inches above the trap. Traps at all bait sets were so placed that the animal would have to cross over them in order to reach the lure. Certain peculiarities observed in catches made at such sets give some indication of travel and approach toward food of the fur-bearers in question.

Opossums were usually caught by a front or hind foot, but 2 males and a female were each taken by a front and a hind foot in the same trap. One small female was caught by the two front and a hind foot in a no. 2 trap. Three opossums, a male and 2 females, were caught only by the tail, and one male was caught by a hind foot and the tail in the same trap. Two medium-sized females opossums were once taken in the same trap, one by a hind and the other by a fore foot. All of the above were taken in bait sets except the male caught by the tail, which was captured in a blind set on a log. This case indicates that opossums at times drag or at least lower their tails while traveling. The other cases suggest that movement is clumsy and that steps are short and close together when approaching food.

Of the 142 opposums trapped only one demonstrated agility and intelligence superior to that commonly ascribed to the species. This was an instance

in which a large male opossum presumably learned to remove bait stapled to a gum tree some 14 inches above the trap. Baits were removed for 5 consecutive nights, and as the ground was covered with freshly fallen leaves, on which tracks would not show, I could not make an identification. After the third loss the trap was placed several inches farther from the gum in order to capture a supposedly larger animal, such as a fox. After the fourth loss the bait was raised to about 3 feet above the ground; and when it disappeared without a catch the fifth time, 3 additional traps were set around the tree and the opossum was taken the first night afterwards. The animal bore no signs of previous capture, and I have no explanation for the behavior described.

Minks and raccoons, in contrast to opossums, were never caught by more than one foot in the same trap. In several instances minks removed the bait by standing to one side of the trap, and in some of these cases the animals were taken later by setting an additional trap to one side of the original set.

Post-capture activities of opossums ranged from a slight disturbance of the ground cover to gnawing through bushes a half-inch in diameter. In cases such as the latter all leaves and trash in reach of the animal were usually raked into a large pile near the point where the trap was fastened. Trapped opossums, at my aproach, usually feigned death, though some individuals remained on foot, bared the teeth, and gave the characteristic gutteral hiss. Trapped opossums were never observed to burrow.

Mink, in all except drowning sets, struggled wildly, and a good part of such effort was used in burrowing, particularly if capture was near a high bank, a stump or a log. Undrowned mink were almost always found in the deepest cavity available, or were observed to retreat into such, when I visited the traps. Little wood-gnawing was observed, and as shown in Table 6, a large percentage of the minks trapped apparently attempted to escape in water and were subsequently drowned.

Raccoons, probably due to their size and strength as much as to their courage, made the greatest amount of sign after capture. This consisted of leaf-raking, wood-gnawing, splashing of mud and water, and vigorous milling and pulling. They gnawed through bushes as much as 1½ inches in diameter, and when raccoons were trapped on logs all bark and loose sap-wood within reach was usually chewed or clawed off. They were never observed to burrow while in traps, but at my approach in running the line, they usually made some effort to hide or retreat. One, taken on dry land, flattened out as close to the ground as possible, head between the fore paws, and remained in this position until I had advanced to within a few yards. Others were observed to hide or cower in a similar manner.

The one weasel taken was still alive when the trap was visited, but was the most ferocious and defensive animal I have ever seen in a trap. The animal, a full grown male, resisted for some time my efforts to dispatch it, though the only movement it could make was a sidewise or downward jerk

of the head and body. This he did repeatedly and with unbelievable swiftness. The one red fox trapped squatted close to the ground, but when I approached to within a few steps he began to leap wildly from side to side.

All species, but especially raccoons and opossums, ate or at least removed and destroyed the bait after capture in such sets. Minks would sometimes leave bait in its original position, particularly if it was old or decayed. In some instances minks and raccoons pulled fresh baits from trees or stakes and dropped the torn pieces to the ground. These reactions were probably due to nervousness and physical stress. Few opossums, after being taken in baited traps, scattered food baits, fresh or old, around the sets, indicating that this species may be less responsive than minks and raccoons to alarm. As opossums removed, and undoubtedly ate, the baits, this may also indicate that they take food under more abnormal conditions than the other two species.

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Burrows and Trails from Pennsylvanian Rocks of Texas

Carroll Lane Fenton and Mildred Adams Fenton

In another paper,[1] we have called attention to the existence of snail burrows in the Brazos River sandstone, a member of the Pennsylvanian Garner formation of Scott and Armstrong,[2] or the lower Mineral Wells of Plummer and Moore. This paper describes other burrows, some molluscan and some of arthropod origin, from the same sandstone. All were collected at the exposure on U. S. Highway 80 N, at the escarpment formed by the Brazos River sandstone, west of Millsap, Parker County, Texas. Locality is not indicated in the descriptions.

Some readers may question the desirability of distinguishing such problematic fossils as these by generic and specific names. The answers to this question are two, one practical and one biologic.

On the practical side, it seems evident that in the Brazos River sandstone, as in many other sandstones and sandy shales, the recorded fauna consists chiefly or wholly of burrows and trails. If these traces possess the uniformity of character which justifies their use in interpretation and correlation, they can be satisfactorily used only in the form of genera and species.

That the traces do possess such uniformity seems evident, even from the small collections at hand. Each group to which a name is applied seems stable within a range no greater than that of ordinary petrifactions.

Our observations, and those of biologists whom we have consulted, indicate that burrowing annelids, molluscs and arthropods make traces of definite and stable character. In many cases, distinctions are constant between species; in others they hold for genera. In snails, crabs and some annelids, we have found both generic and specific distinctions in trails, correlation with genera and species of living organisms. In short: in modern seas, characters of burrows and trails have observable taxonomic meaning. It seems only proper for us to assume similar meaning for fossil traces, and to give them taxonomic recognition.

Descriptions

Aulichnites gen. nov.

Aulos, tube; *ichnos*, footprint; *lithos*, stone

Genoholotype: *Aulichnites parkerensis* sp. nov.

Description.—Burrow of a shelled and presumably scavenging snail inhabiting sandy shoals. The burrow is elevated and filled by sand in compressed, oval layers which are concave anteriorly and markedly convex upward. These

1 This Journal, **18**:452-453, 1937.
2 Univ. Texas Bull. **3232**:106, 108, 1933.

layers form two parallel ridges separated by a deep, angular furrow; there is no elevated mesial ridge, as in *Olivellites* F. and F. and the doubtful *Cylindrites* figured by Rieth.[3] Margins of the burrow marked by sharp furrows, as if sand had collapsed abruptly during forward movement of the snail.

Aulichnites parkerensis sp. nov.

Pl. 1, Figs. 1-2

Description.—General characters are those of the generic description. The burrows curve in long, open or closed loops whose inner portions are narrower than the outer. Widths range from 5 to 11.4 mm.

To this species also is assigned the negative of Plate 1, Fig. 2. It is deeply undercut, indicating elevation of the burrow. The under surface is smooth, but lateral surfaces show ridges and depressions comparable to those on the upper surface of the holotype.

Holotype.—46,976; *Paratypes.*—46,977-46,978 Princeton University.

Tropidaulus gen. nov.

Tropis, keel; *aulos*, tube

Genoholotype: *Tropidaulus magnus* sp. nov.

Description.—Depressed burrows known only from elevated negatives in sandstone. The under surface shows faint transverse wrinkles and an abruptly elevated median ridge or keel. Nature of the marks is problematic; they suggest *Aulichnites* in reverse, and may be the work of arthropods or large annelids, rather than snails.

Tropidaulus magnus sp. nov.

Pl. 1, Fig. 4

Remarks.—Since the genus is monospecific, characters of this species are stated in the generic description. Width of the holotype ranges from 16 to 21.5 mm.

Holotype.—46,979 Princeton University.

Ptychoplasma gen. nov.

Ptyche, ridge; *plasma* cast

Genoholotype: *Ptychoplasma excelsum* sp. nov.

Description.—Deep furrows and burrows, apparently dug by pelecypods. Negatives consist of an abrupt ridge obliquely fluted, grading into a series of conical layers pressed into each other; these apparently were made by a posteriorly directed foot which pushed the animal through sandy mud and compressed sediment behind it. Above this ridge is a much wider mark, also obliquely fluted; abrupt ridges apparently were made by edges of the valves. Where the furrows became burrows, marks of the foot widen.

3 Geol. Pal. Abh., n. F. **19**(4):32, 1932.

Ptychoplasma excelsum sp. nov.

Pl. 2

Remarks.—The generic description serves for this species. All specimens are negatives, apparently consisting of sediment pushed behind them by moving pelecypods.

Holotype.—46,990 Princeton University; *Paratype.*—46,991 Princeton University.

Camptocladus gen. nov.

Kampto, I bend; *clados,* twig

Genoholotype: *Camptocladus intertextus* sp. nov.

Description.—Branched, flexuous, intertwined burrows preserved as sandy fillings. Texture of those fillings is too coarse to preserve small markings, but the shapes and manner of branching suggest modern crab burrows described by Hayasaka.[4] The genus is proposed on the assumption that the burrows are of crustacean origin, with a potential range of species which exceed true generic limits.

Camptocladus intertextus sp. nov.

Pl. 3

Description.—Branched, intermingled burrows which are depressed to circular in cross section; some end in club-shaped expansions while others terminate acutely.

Holotype.—46,992; *Paratypes.*—46,993-46,994 Princeton University.

Arthraria? sp.

Pl. 1, Fig. 3

Remarks.—Three irregular burrows appear to be connected by surface trails, and perhaps are the work of snails. They closely resemble a specimen from the Medina of the Niagara Gorge, which we have discussed and illustrated elsewhere.[5]

Figured Specimen.—46,980 Princeton University.

Xiphosuran Trails

Remarks.—One slab contains several arthropod trails in negative. They consist of ridges 1.5 to 2.4 mm. wide and 5 to 12 mm. long, spaced 1 to 4 mm. apart. Between these run broken ridges. The former appear to fill impressions made by bunched appendages, pushing against mud; the latter suggest filled marks of a stout telson. The entire track, too indistinct for formal description, suggests that of an animal resembling the Xiphosuran *Prestwichia;* some of the longest, sharpest marks are not paired and probably were made by the margin of the cephalothorax.

Specimen.—46,997 Princeton University.

4 This Journal **16**:99-103, 1935.
5 Pan-Am. Geol. **61**:265, 1934.

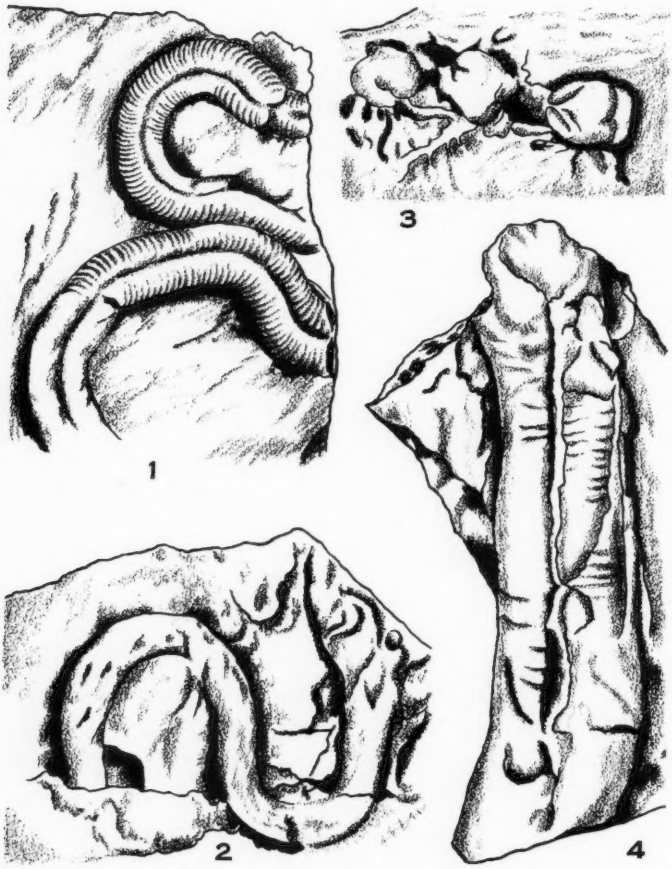


PLATE 1

FIGURES

1–2. *Aulichnites parkerensis* sp. nov.
1. Upper surface of the holotype showing transverse layers and medial furrow. (46,976 Princeton University.)
2. Under surface of a paratype (negative), showing S-curves. (46,978 Princeton University.)
3. *Arthraria?* sp. (46,980 Princeton University.)
4. *Tropidaulus magnus* sp. nov. Under surface of the holotype, showing transverse wrinkles and filled medial keel. (46,979 Princeton University.)

(All figures natural size.)

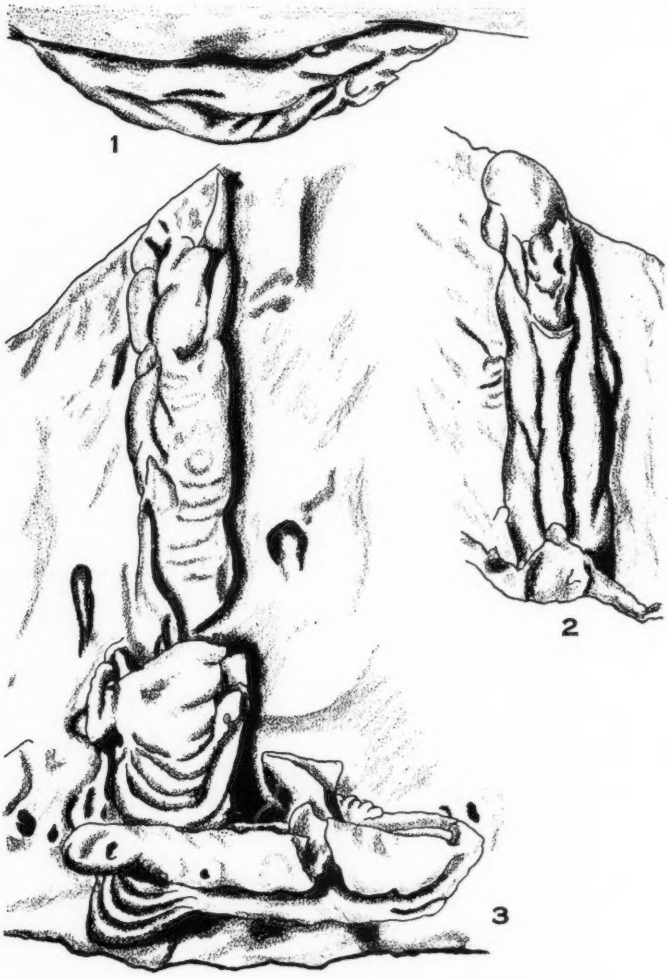


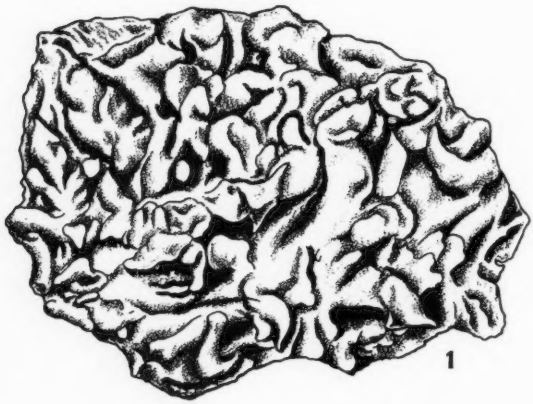
PLATE 2

FIGURES

1–3. *Ptychoplasma excelsum* sp. nov.

1–2. Lateral and inferior views of the holotype, showing conical layers in the medial furrow. (46,990 Princeton University.)

3. Inferior view of two crossed negatives, the larger of which is damaged. (46,991 Princeton University.) (All figures natural size.)



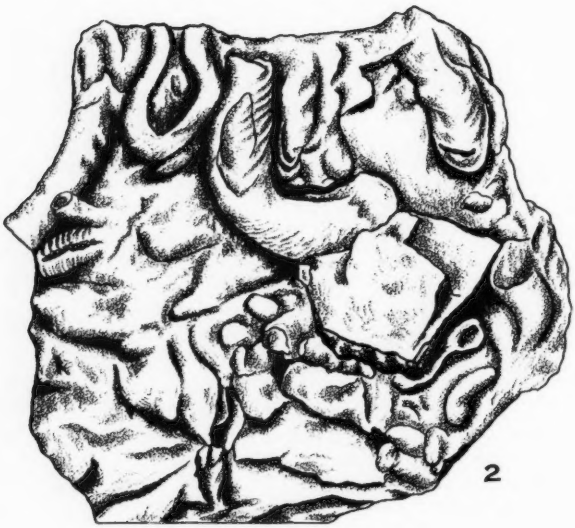


PLATE 3

FIGURES

1–2. *Camptocladus intertextus* sp. nov.

1. Holotype, showing a close tangle of burrow fillings. (46,992 Princeton University.)
2. Paratype, showing burrows of maximum size. Those which bear oblique annulations are *Aulichnites parkerensis*. (46,993 Princeton University.)

(All figures natural size.)

Species and Geographic Distribution of the Lichadacea

Fred B. Phleger, Jr.

This paper undertakes to allocate the species of Lichadian trilobites, of which a revised classification has been published.[1] Descriptions and illustrations have been supplemented by study of specimens in the Museum of Comparative Zoology and several collections in England and Scotland. A few species, based on fragmentary material or described in publications not available to the author, are excluded. Each species name is followed by geologic and regional range, as indicidated in publications.

The writer wishes to thank Professor P. E. Raymond, who supervised this study, as well as the following men, who permitted examination of collections: Professor E. B. Bailey and Drs. Weir and Curry, of the Hunterian Museum, Glasgow; Dr. Murray Macgregor and Mr. F. W. Anderson, of the Scottish Geological Survey; Dr. C. J. Stubblefield, of the Museum of Practical Geology, and Mr. Withers, of the British Museum. Mr. James L. Begg lent part of his collection.

Allocation of Species

Superfamily LICHADACEA Phleger
Family LICHADIDAE Corda
Subfamily LICHADINAE Gürich

Genus PLATOPOLICHAS Gürich (emend.)

Species:

P. avus (Barrande)	D—dly, Bohemia
P. incolus (Barrande)	D—dly, Bohemia
?*P. hispanicus* (Verneuil and Barr.)	Ordovician, Spain
P. kloucekus (Ruzicka)	Lower Ordovician, Bohemia

Genus LICHAS Dalman (s.str.)

Species:

L. laciniatus (Wahlenberg)	Brachiopod shales, Sweden and British Isles
L. dissidens Beyrich	Limestone boulders, Germany
L. platyurus Nieszkowski	Reval, Esthonia
L. conformis Angelin	Leptaena limestone, Sweden
?*L. rudis* Barrande	D—d5, Bohemia
?*L. primulus* Barrande	H, Bohemia
L. palifer Lindström	Gotlandian, Sweden
L. rotundifrons Angelin	E, Gotland
L. keislevensis Reed	Upper Ordovician, British Isles.
L. ferrisi (Weller)	Lower Niagaran, Illinois
L. congruens Reed	Drummock Group, Scotland
L. velatus Steinhart	Boulders, Germany
L. affinis Angelin	Leptaena limestone, Sweden
L. cicatricosus Loven	F2, Baltic region; Leptaena limestone, Sweden
L. browni Sun	Middle Ordovician, China

1 Phleger, F. B., Jr.: Lichadian trilobites, Jour. Pal. **10**(7):593-615, 1936.

Genus METOPOLICHAS Gürich

Species:	
M. hübneri (Eichwald)	Dubowiki, Baltic region (C1b)
M. pachyrhinus (Dalman)	B3a-b, Baltic region; Orthoceras limestone, Sweden
M. convexus (Angelin)	Orthoceras limestone, Sweden
M. verrucosus (Eichwald)	B1, B2, Baltic region; Orthoceras limestone, Sweden
M. celorrhin (Angelin)	Orthoceras limestone, Sweden and Baltic region
M. coniceps (Leuchtenberg)	B2, B3, Baltic region
M. norvegicus (Angelin)	C, Norway
M. patriarchus (Edgell and Wyatt)	Llandeilo, British Isles
M. sinensis Sun	Middle Ordovician, China

Genus MACROTEROLICHAS Phleger

Species:	
M. longirostratus (Schmidt)	B3, Baltic region

Genus URALICHAS Delgado

Species:	
U. riberoi Delgado	Llandeilo, Portugal and France

Genus ARCTINURUS Castelnau

Species:	
A. boltoni (Bigsby)	Clinton, New York and Ontario
A. nereus (Hall)	Niagaran, New York and Arkansas
A. occidentalis (Winchell and Marcy)	Niagaran and Clinton, New York and Tennessee
A. pugnax (Winchell and Marcy)	Niagaran of Illinois

Subfamily ECHINOLICHADINAE Phleger

Genus PSEUDOTUPOLICHAS Phleger

Species:	
P. ornatus (Angelin)	Gotlandian, Baltic region, Sweden
P. visbeyensis (Lindström)	Gotlandian, Baltic region, Sweden
P. plicatus (Lindström)	Gotlandian, Baltic region, Sweden
P. canadaensis (Billings)	Anticostian, Anticosti
P. araneus (Lindström)	Fråη limestone, Sweden

Genus ARCTINUROIDES Phleger

Species:	
A. chicagoensis (Weller)	Niagaran, Illinois

Genus GASPELICHAS Clarke

Species:	
G. forillonius Clarke	Oriskany of Gaspe, Canada

Genus ECHINOLICHAS Gürich

Species:	
E. eriopis (Hall)	Onondaga, New York
E. bigsbyi (Hall)	Helderberg, New York
E. hispidus (Hall)	Onondaga, New York

Genus TERETASPIS Hall

Species:	
T. grandis Hall	Onondaga, New York and Ontario

Genus CERATOLICHAS Hall and Clarke

Species:

C. gryps Hall and Clarke	Onondaga, New York
C. dracon Hall and Clarke	Onondaga, New York

Genus RADIOLICHAS Reed

Species:

R. araneus (Holzapfel)	Massenkalk, Rhine Valley, Germany

Subfamily HOMOLICHADINAE Phleger

Genus HOMOLICHAS Schmidt

Species:

H. depressus (Angelin)	C2, Baltic region; boulders in Sweden
H. deflexus (Sjögren)	D2, Esthonia
H. eichwaldi (Nieszkowski)	E2, Baltic region; boulders in Sweden
H. pahleni Schmidt	D1, Baltic region
H. angustus (Beyrich)	Lyckholm limestone, Baltic region
H. lindströmi Pompecki	Upper Silurian of Prussia
H. gotlandicus (Angelin)	E, Gotland
H. inconsuetus (Raymond)	Trenton, New York
?*H. aculeatus* (Angelin)	Chasmops limestone, Sweden
H. validus (Linnarson)	Berichiakalk, Sweden
H. faberi (Miller)	Maysville, Ohio
H. pumulus (McCoy)	Carickadaggen slate, Ireland

Genus TRIMEROLICHAS Phleger

Species:

T. marginatus (Lindström)	Upper Silurian of Germany and Scotland
T. clintonensis (Foerste)	Clinton, North America
T. breviceps (Hall)	Niagaran, New York
T. trentonensis (Hall)	?Trenton, New York

Genus CYPHOLICHAS Phleger

Species:

C. branconis (Pompecki)	Boulders, Germany

Genus HOPLOLICHOIDES Phleger

Species:

H. conicotuberculatus (Nieszkowski)	C1 and C2, Esthonia
H. medius (Pompecki)	Echinosphaerites limestone, Prussia
H. plautini (Schmidt)	Echinosphaerites limestone, Baltic region
H. furcifer (Schmidt)	C1 and Echinosphaerites limestone, Baltic region
H. longispinus (Schmidt)	Boulders, Germany; C2, Baltic region

Genus HOPOLICHAS Dames

Species:

H. tricuspidatus (Beyrich)	Middle Ordovician, Sweden; Boulders, Germany; Echinosphaerites limestones, Esthonia
H. quadricornis Steinhart	Gray limestone and brown shale, Prussia

Genus CYRANOLICHAS Phleger

Species:

C. proboscidius (Dames)	Boulders, northern Germany

Genus LEIOLICHAS Schmidt

Species:

L. illaenoides (Nieszkowski)	Jewe and Kegel, Esthonia
L. gageli (Pompecki)	Boulders, northern Germany
?*L. crassirhachis* (von Meyer)	Boulders, Germany
?*L. angustus* (Beyrich)	Reval, Esthonia

Genus CONOLICHAS Dames

Species:

C. aequilobus (Steinhart)	D2, Esthonia; Boulders, Germany
C. triconius Dames	C2, Esthonia; boulders, Germany
C. schmidti Dames	D2, Esthonia
C. cornutus (Hall and Clarke)	Middle Trenton, New York

Subfamily TETRALICHADINAE Phleger
Genus TETRALICHAS Phleger

Species:

L. laevis (Eichwald)	*Platystrophia lynx* limestone, Kirna
T. periformis (Warburg)	Leptaena limestone, Sweden
T. parvulus (Warburg)	Leptaena limestone, Sweden
T. atavus (Warburg)	Leptaena limestone, Sweden
T. dalecarlicus (Angelin)	Leptaena limestone, Sweden
T. tibetanus (Salter)	Ordovician, India
T. ardmillensis (Reed)	Llandeilo, Scotland
T. holmi (Schmidt)	Wesenberg, Baltic region
T. illaeniformis (Wigand)	Boulders, Germany
T. clermontensis (Slocom)	Lower Maquoketa, Iowa
T. obtusicaudatus (Troedsson)	Ordovician, Greenland
T. concinnus (Angelin)	Gotlandian, Sweden
T. jukesi (Billings)	Quebec group, Newfoundland
?*T. macrocephalus* (Eichwald)	Orthoceras limestone, Esthonia
T. transversus (Reed)	Llandeilo, Scotland
T. hibernicus (Portlock)	Llandeilo, Ireland
T. wahlenbergi (Warburg)	Leptaena limestone, Sweden
T. latifrons (Warburg)	Leptaena limestone, Sweden
T. trentonensis (Conrad)	Martinsburg shale, Pennsylvania and Virginia
T. narrawayi (Foerste)	Trenton, Canada
T. prominulus (Raymond)	Lower Ordovician, Virginia
T. minganensis (Billings)	Chazy, eastern Canada, Vermont, New York, Virginia
T. conifrons (Ruedemann)	Trenton, New York
T. harrisi (Miller)	Richmond, Ohio
T. melberbiensis (Reed)	Dufton shale, British Isles

Genus KERAKEPHALICHAS Phleger

Species:

K. rhinoceras (Slocom)	Upper Maquoketa, Iowa
K. bicornis (Ulrich)	Maquoketa, Minnesota

Genus ACROLICHAS Foerste

Species:

A. cucullus (Meek and Worthen)	Kimmswick, Missouri, Illinois

Genus AMPHILICHAS Raymond

Species:

A. lineatus (Angelin)	Leptaena limestone, Sweden
A. brevilobatus (Tornquist)	Leptaena limestone, Sweden

Genus PROBOLICHAS Phleger

Species:

P. robbinsi (Ulrich)	Upper Cincinnatian, Minnesota

Family TROCHURIDAE Phleger
Subfamily TROCHURINAE Phleger
Genus TROCHURUS Beyrich

Species:

T. speciosus (Beyrich)	E2, Bohemia; St. Johann limestone, Germany
?*T. verrucosus* (Salter)	Wenlock limestone, British Isles
T. tornquisti Gürich	Leptaena limestone, Sweden
T. byrnesanus (Miller and Gurley)	Laurel, Indiana
T. phlyctainoides (Green)	Niagaran, Ohio, Indiana, New York
T. propinquus (Barrande)	E-e2, Bohemia
T. interjectus (Hawle and Corda)	St. Johann limestone, Germany
T. depauperatus (Van Ingen)	St. Clair, Arkansas
?*T. anglicus* (Beyrich)	Wenlock series, Girvan
?*T. tuberculatus* (Weller)	Trenton, New Jersey
T. palmatus (Barrande)	E, Bohemia; Leptaena limestone, Sweden
T. geikei (Nicholson and Etheridge)	Upper Bala, British Isles

Genus DICRANOGMUS Hawle and Gorda

Species:

D. simplex (Barrande)	E-e2, Bohemia
D. pustulatus (equals D. simplex)	
D. aequalis (Tornquist)	Leptaena limestone, Sweden
D. maius Reed	Silurian, British Isles

Genus RICHTERARGES Phleger

R. ptyonurus (Hall)	Cobleskill, New York
R. gibbus (Angelin)	Gotlandian, Sweden

Genus DIPLOLICHAS Phleger

Species:

D. maueri (Novak)	Lower Devonian, Germany

Genus AKANTHARGES Phleger

Species:

A. gourdonni (Barrois)	Devonian of France

Subfamily EUARGINAE Gürich (emend)
Genus EUARGES Gürich

Species:

E. haueri (Barrande)	F-f2, Bohemia, Portugal
E. contusus (Hall)	Onondaga, New York
E. pusillus (Angelin)	Gotlandian, Sweden
E. laticeps (Angelin)	Gotlandian, Sweden
E. branikensis (Barrande)	G-gl, Bohemia
E. leuchtenbergi (Hawle and Corda)	(equals E. haueri)
?*E. sexlobatus* (Roemer)	Middle Devonian, Germany
E. meridionalis Frech	Lower Devonian, France
E. salteri (Fletcher)	Dudley, British Isles
E. hirsutus (Fletcher)	Dudley, British Isles
E. bucklandi (Milne-Edwards)	Dudley, British Isles
E. devonianus (Whidborne)	Devonian, North America
?*E. tuberculatus* (Reed)	Dudley, British Isles
?*E. bifurcatus* (Reed)	Keisley limestone, British Isles
E. decheni (Holzapfel)	Martenberge limestone, Baltic region
E. australis (McCoy)	Silurian of Australia
E. nitidulus (Barrande)	Middle Devonian, Bohemia
E. beryllifer (Richter)	Middle Devonian, Germany
E. parvulus (Novak)	Middle Devonian, Germany

Genus HEMIARGES Gürich

Species:

H. wesenbergensis (Schmidt)	E2, Baltic region; Llandeilo, Scotland
H. palianus (Clarke)	Trenton, Minnesota
H. warburgae Troedsson	Ordovician, Greenland
H. serus Reed	Mulloch Hill group, Girvan, Scotland

Genus CHONEILOBARGES Phleger

Species:

C. macculochi (Reed)	Upper Bala, Scotland

Genus CERATARGES Gürich

Species:

C. armatus (Goldfuss)	Eifel, Germany

Genus CRASPEDARGES Gürich

Species:

C. wilcanniae Gürich	Lower Devonian, Australia
C. scutalis (Reed)	Dudley, England
C. ambigua (Barrande)	E-e2, Bohemia
C. heterocyclyta (Barrande)	E-e2, Bohemia

Genus EIFLIARGES R. and E. Richter

Species:

E. caudimirus R. and E. Richter	Eifel, Germany

Genus MEPHIARGES R. and E. Richter

Species:

M. mephisto R. and E. Richter	Middle Devonian, Germany

Subfamily DICRANOPELTINAE Phleger

Genus DICRANOPELTIS Hawle and Corda

Species:

D. scabra (Beyrich)	E, Bohemia; St. Johann limestone, Germany
D. polytona (Angelin)	D-E, Sweden
D. parva (Barrande)	F, Bohemia
D. aspera (Hawle and Corda)	Kesel limestone, Germany
D. telleri Weller	Niagaran limestone, Wisconsin
D. woodwardi Reed	Wenlock, British Isles

Genus DICRANOPELTOIDES Phleger

Species:

D. decipiens (Winchell and Marcy)	Niagaran of Illinois, Wisconsin
D. triquetris (Lindström)	Silurian, Gotland
D. elegans (Tornquist)	Leptaena limestone, Sweden
D. arkansana (Van Ingen)	St. Clair, Arkansas

Genus MAKROMUKTIS Phleger

Species:

M. nasuta (Weller)	Niagara limestone, Wisconsin

Subfamily PHLATYLICHADINAE Phleger

Genus PLATYLICHAS Gürich

Species:

P. margaritifer (Nieszkowski)	F2, Baltic region; Borkholmer, Esthonia
P. laxatus (McCoy)	F1, Baltic region, Leptaena limestone, Sweden; Bala, British Isles
P. scotius Reed	Lower Landovry, British Isles
P. angulatus Warburg	Leptaena limestone, Sweden
P. latus Tornquist	Leptaena limestone, Sweden

P. bottniensis (Wiman)	Chasmops and Leptaena limestones, Sweden
P. cicatricosus (Schmidt-non Loven)	F2, Baltic provinces; Leptaena limestone Sweden
P. robustus Warburg	Leptaena limestone, Sweden
P. nasutus (Wigand)	Leptaena limestone, Sweden, boulders in Germany
P. vicinus Reed	Drummock Group, Girvan, Scotland
P. crescenticus Reed	Drummock Group, Girvan, Scotland
P. Traivensis Reed	Drummock Group, Girvan, Scotland
P. wegelini Warburg	Leptaena limestone, Sweden
P. barrandei (Fletcher)	Dudley, British Isles
P. grayi (Fletcher)	Dudley, British Isles
P. celandicus (Angelin)	Chasmops limestone, Sweden
?*P. sexspinus* (Angelin)	Chasmops limestone, Sweden

Genus AUTOLOXICHAS Phleger

Species:

A. st. mathiae (Schmidt)	D1 and D2 of Esthonia

Genus LINGUCEPHALICHAS Phleger

Species:

L. planifrons (Angelin)	Leptaena limestone, Sweden

Geographic Distribution

The Lichadacea arose in the Baltic region of northern Europe, in which continent most of their evolution centered. *Metopolichas* is found in the Baltic region and in Scandinavia. *Platopolichas* is an offshoot from the basal stem of the Lichadinae which was isolated in Bohemia.

The first evolutionary expansion occurred in northern Europe during the Middle Ordovician, and fourteen genera are there represented. The earliest American lichads, *Tetralichas* minganensis (Billings) and *Tetralichas jukesii* (Billings), are found in the Chazy of eastern North America. It is interesting to observe that *Tetralichas* occurs in North America in older Middle Ordovician rocks than in Europe. The first undoubted European tetralichad occurs in the Wesenberg, in the upper Middle Ordovician. Specimens of *Tetralichas* probably will be found in the Lower or basal Middle Ordovician of Europe. The Tetralichadinae are abundant in the Middle and upper Ordovician of North America; *Kerakephalichas* and *Probolichas* are restricted to that continent.

Homolichas and *Hemiarges* occur in the Middle and Upper Ordovician of North America. The Lichadinae apparently are not represented on that continent until the Silurian, but the Silurian genera *Arctinurus* and *Arctinuroides* are confined to it, while representatives of *Trimerolichas, Pseudotupolichas,* and *Lichas* are present in the Silurian. During the Devonian the Lichadinae gave rise to a variety of large and spinose forms which are confined to North America *(Terataspis, Ceratolichas, Echinolichas,* and *Gaspeliches).*

Hemiarges undoubtedly migrated to North America from northern Europe at approximately the same time as *Tetralichas.* Both genera are found in the Ordovician of northern Greenland. The Trochuridae, with the excep-

tion of the Platylichadinae, are well represented on the American continent in the Silurian, but only one Ordovician species and two Devonian species have been reported.

Most Devonian trochurids are from central Europe, having become established there during the Middle and Upper Silurian.

The Platylichadinae are confined to northern Europe.

Two lichadian species have been found in Australia, *Euarges australis* McCoy, of Silurian age, and *Craspedarges wilcanniae* Gürich, Lower Devonian in age. *Tetralichas tibetanus* (Salter) is from the Ordovician of India. *Metpolichas sinensis* Sun and *Lichas browni* Sun are from the Middle Ordovician of China.

Existing evidence indicates that the lichads which migrated to the American continent from northern Europe came by way of the British Isles and northern Greenland. In this connection it is interesting that *Tetralichas jukesii* occurs in the Chazy of Newfoundland. All known North American species appear to be confined to the eastern half of that continent; no species has been reported farther west than Missouri.

From evolutionary possibilities, it seems likely that *Dicranopeltis, Trochurus,* and *Lichas* migrated to North America during the Silurian.

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A Method of Generic Comparison

Fred B. Phleger, Jr.

In a recent monographic study of the Lichadacea,[1] the author felt the need for a simplified method of tabulating characters of the various genera. As a result, a check-chart of generic characters was developed. The chart used in the study of the Lichadacea is presented as an example of the method here described. A comparison of this with the descriptions used in a previous paper[2] may clarify this discussion.

After a study of all genera of the superfamily, the characters of generic importance have been compiled, avoiding duplication and omitting those characters considered unimportant, and each character has been given a number. In the lichadian trilobites, one set of numbers has been used for the characters of the cranidium and another for those of the pygidium. Other groups of fossils would require different listing. Characters have been listed by number on the chart, and the characters of each genus have been checked by number. An index to the characters represented by the numbers on the chart has been placed on the page opposite it.

This method has many advantages. In writing final generic descriptions, reference to the chart has made them brief and as exact as material will permit, eliminating unnecessary words and inaccurate phrasing. It has simplified certain concepts, for use of the check-chart presented many possibilities of interpretation. Where the characters important in them are known, the larger natural groups are indicated at a glance. Study of the chart for possible groupings has produced results which can be determined by reference to descriptions and illustrations. Comparison of genera, in writing descriptions, is also much simplified, and indications of parallelism are easily ascertained.

The primary advantage of listing in one place all generic characters of a group of genera is it discourages confusion and repetition. In Lichadacea it became necessary to combine many characters which originally seemed distinct, and in this the chart was an aid. It also concentrated a great mass of information into a comparatively small unit, where it could be compared and correlated easily.

This method is primarily of value to the worker in the laboratory. Whether or not the chart should be included in the publication of any particular monograph depends largely upon individual circumstances. As yet, the methods has been applied to genera only, and I doubt that it can be used

1 Phleger, F. B., Jr., Lichadian Trilobites, Jour. Pal. **10**(7):593-615, 1936

2 op. cit.

profitably in description of species. It appears to work best in monographic studies of families or larger groups.

AMHERST COLLEGE,
AMHERST, MASS.

LIST OF GENERIC CHARACTERS OF THE LICHADACEA

GLABELLA

1. Tricomposite lobes.
2. Bicomposite lobes.
3. Basal lobes.
4. Longitudinal furrows reach occipital lobe.
5. Longitudinal furrows faintly incised.
6. Third lateral furrows present and complete.
7. Third lateral furrows indicated mesally only.
8. Posterior lobes outside anterior lobes.
9. Doubly bicomposite lobes.
10. Quadricomposite lobes.
11. Glabella strongly arched anteriorly. a—produced in a proboscis-like projection. c—produced in cone. t—covered with spiny tubercules.
12. Occipital spine or spines.
13. Elongation.
14. Second lateral furrows indicated mesally.
15. Furrows of lateral lobes very deeply impressed.
16. Third lateral furrows extend across axial lobe.
17. Fusion of third lateral lobes or of posterior bicomposite lobes with fixed cheeks.
18. Fusion of third lateral lobes with basal lobes.
19. First lateral furrows obsolete.
20. Rim of cephalon produced anteriorly in a tongue-like projection.
21. Glabella supports one or more spines.

PYGIDIUM

1. Three pairs of discrete ribs.
2. Four pairs of ribs.
3. Two anterior pairs of ribs only have free points.
4. Axial lobe narrows posteriorly; p-narrows to a point.
5. Axial lobe flares posteriorly.
6. Postaxial area produced in one or two points or spines.
7. No median furrow on third pair of ribs.
8. Ribs have rounded ends.
9. Two rings on axial lobe.
10. Three rings on axial lobe.
11. Four rings on axial lobe.
12. One ring on axial lobe.
13. Pygidium almost smooth, with no discrete ribs.
13. Pygidium almost smooth, with no discrete ribs.
14. Apparently no rings on axial lobe.
15. Several rings on axial lobe.
16. Two short marginal points on each of last two pairs of ribs.

CHART OF GENERIC CHARACTERS

Glabella Pygidium

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
PLATOPOLICHAS		x	x			x																x		x			x			x						
LICHAS		x	x			x																	x		x			x								
METOPOLICHAS		x	x			x			x														x		x			x								
URALICHAS		x	x			x			x		x	x											x			x		x								
ONCHOLICHAS				x					x														x		x			x								
TRIMEROLICHAS	x		x	x																																
ARCTINURUS		x		x														x				x			x						x					
MACROTEROLICHAS		x	x			x			a				x																							
ARCTINUROIDES				x					x																											
GASPELICHAS				x					x	x	x	x																								
ECHINOLICHAS				x					x	t												x			x	x		x								
TERATASPIS				x					x	t	x	x							x			x			x	x					x					
CERATOLICHAS				x					x	x	x								x																	
RADIOLICHAS				x					x													x				x						x				
HOMOLICHAS	x		x	x						x													x		x			x								
CYPHOLICHAS	x		x							x		x		x																						
HOPLOLICHOIDES	x		x	x							x												x			x	x		x							
HOPLOLICHAS	x		x	x							x								x				x			x	x		x							
CYRANOLICHAS	x		x	x						a	x												x			x	x		x							
LEIOLICHAS	x		x																															x	x	
CONOLICHAS	x		x							c												x			x			x								
TETRALICHAS				x					x														x	x				x								
KERAKEPHALICHAS				x					x										x																	
AMPHILICHAS		x			x		x																													
PROBOLICHAS				x					x	a																										
TROCHURUS		x	x	x		x				x				x	x							x		x				x								
DICRANOGMUS		x	x	x		x				x						x		x						x												
RICHTERARGES		x		x		x				x						x		x						x	x		x			x						
DIPLOLICHAS						x			x					x																						
AKANTHARGES		x				x											x		x			x						x								
EUARGES				x		x			x							x	x					x			x				x							
HEMIARGES				x		x			x								x					x														x
CHONEILOBARGES				x		x			x				x		x	x	x					x														x
CERATARGES					x			x		x	x					x						very spinose														
CRASPEDARGES		x		x		x									x	x						x			p			x								x
EIFLIARGES				x		x			x		x			x	?	x						see description														
MEPHIARGES				x		x			x				x		x	x																				
DICRANOPELTOIDES		x	x	x		x																x			n				x							
DICRANOPELTIS		x	x	x		x									x									x	x				x							
MAKROMUKTIS		x	x	x		x																		x	x				x							
PLATYLICHAS		x	x	x		x										x								x		x				x						
AUTOLOXOLICHAS		x	x			x							x		x																					
LINGUCEPHALICHAS		x	x	x		x										x			x			x				x				x						

Secondary Blinding among the Phacopid Trilobites and its Significance

David M. Delo

Summary

Secondary blinding occurs in one major group of Phacopid Trilobites (Family *Phacopidae*). Intermediate stages between the normal condition and total blindness show migration of the eyes toward the antero-lateral cephalic margin and reduction of the visual area. The eyes disappear before reaching the cephalic border, but migration of the facial suture continues, in one genus *(Ductina)* assuming a secondarily hypoparian position. Disappearance of the eye before reaching the cephalic margin agrees with Lalicker's observation that eyes first appear on the dorsal surface of the cephalon.

This paper is the result of studies pursued at the Museum of Comparative Zoology, Cambridge, Mass., other results of which have been published previously. The writer wishes to express his gratitude to Professor Percy E. Raymond for his criticism and assistance during preparation of the manuscript.

I.—Examples of Eye Degeneration

The phacopids occupy an unique position among the trilobites because of the nature of the eyes. These have been described as aggregate or schizochroal, and eyes of this type are confined solely to this group. In general "the individual lenses are comparatively large, distinct from one another, each lying in its own socket. There is, however, a thin membrane which covers all those in any one aggregate, and is a continuation of the general integument of the body. This membrane is continued as a thickened infolding which forms the sockets of the lenses." (Raymond, 1920: 97).

Raymond remarks elsewhere (1913: 697), that, "the size of the facets varies from more than .5 mm. in some. . . to from 6-14 in the width of one mm. in other trilobites."

Not only is the group characterized by possession of this singular type of visual organ, but within it there is great variation in the size of the eyes, and in the size and number of the facets. In general, the *Dalmanitidae* possess large eyes and show little relative variation in the number of facets. On the other hand the *Phacopidae* usually exhibit smaller eyes with larger facets, which show an extraordinary variation in size and position.

In several branches of this latter family *(Phacopidae)*, the eyes pass through a rather definite series of changes, which lead, in some species, to complete secondary blinding.

The normal position of the eyes is near the glabella, elevated nearly to its level or, in some species, extending above it. The normal visual area has the shape of a truncated semicone, and the facial suture describes a forward

and outwardly directed curve around its upper margin. In all observed cases in which there is a tendency toward reduction in the size of the visual area, the eyes have migrated toward the antero-lateral margin of the cephalon, the amount of such migration being roughly proportional to the degree of obsolescence. In their most reduced stages, the eyes are on the anterior slope of the cheek areas, and in some cases (*Dienstina diensti* R. & E. Richter), at the anterior ends of the dorsal furrows. Reduction of the visual area is accompanied by a concomitant change in shape. The anterior and posterior rows of facets disappear progressively and the remaining vertical rows become shorter. This process changes the outline of the visual area from that of the truncated semi-cone mentioned above to "kidney-shaped" ("Nierenform" of Richter), so that the palpebral lobe becomes flattened against the cheek. In these stages the facial suture still curves forward around the upper margin of the eyes, but the curve is of increasingly larger radius. This pattern of the visual area is found in varying degree in species of the genus *Reedops* Wedekind, 1914, especially in *R. bronni* and *R. hoeninghausi* from strata of Silurian age in the Bohemian Basin. It is also present in *Denckmannites limarius* from the Upper Devonian of Germany, and in *Ormathops microphthalmus* (Novak) from the Lowest Ordovician shales near Prague.

At a later stage in the obsolescence of the eyes, there is further reduction in the number of facets, each of which becomes proportionally larger. The visual area becomes elliptical, and the facial suture, instead of curving forward along the posterior margin of the visual area, curves backward. The Richters (1926: 10 ff.) have called this pattern of the visual area the "cryptothalmus-tracht." It occurs in *Ormathops barroisi* (Novak) from Stage D 1 gamma in the Bohemian Basin, in *Denckmannites volborthi* and its allies of Silurian age, *Dienstina diensti* R. & E. Richter, *Eocryphops kayseri* (Hermann), *Phacops pentops* Ivor Thomas, *Cryphops cryptophthalmus* (Emmrich) from the Upper Devonian, and in many other species of the *Phacopidae*.

The Richters have defined it as follows: "Sehfläche elliptisch werdend, nach innen konvex begrenzt, Augendeckel sich einebnend." (1926: 132).

This "crytophthalmus-pattern" is found only in species in which the eyes have migrated far forward upon the anterior slope of the cheeks. The facets are greatly reduced in number in most there are not more than 15, and they are individually enlarged. The visual area, because of its position, is directed forward.

Only in one genus of the *Phacopidae, Nephranops* R. & E. Richter, does the "cryptophthalmus-pattern" fail to appear, although complete atrophy of the eyes occurs. The blind species, *N. incisus* (A. Roemer) possesses a kidney-shaped swelling on the anterior slope of the cheek area, around which the facial suture describes a curve. The species with eyes have a kidney-shaped visual area.

Two genera of the *Phacopidae, Trimerocephalus* and *Dianops,* and one genus of the *Phacopidellinae, Ductina,* are entirely blind. A slightly rounded swelling marks the former position of the eye in some species of *Trimerocephalus*. In others, no trace of the swelling is discernible. In all species of

this genus, the facial suture describes a curve from the cephalic border across the anterior slope of the cheek. It cuts the cephalic margin a considerable distance in front of the genal angle, and crosses the lateral border at a high angle.

Dianops, as figured by the Richters, shows no trace of the eyes. The posterior branch of the facial suture cuts the cephalic margin near the genal angle where it crosses the border at a very low angle. Opposite the anterior end of the dorsal furrow, the anterior branch of the suture describes a shallow backward curve, which varies in concavity in different species. The suture is confined to the cephalic border in all known species of the genus.

Ductina ductifrons marks the acme of blinding in the *Phacopidellinae.* There is no trace of eyes and the facial suture extends straight along the cephalic margin.

There is a group of small-eyed and blind *Phacopinae* in the Upper Silurian (Obere Steinhornschichten) of the Kellerwald. Several species have been described by Wedekind (1914), but his figures and descriptions are insufficient to permit generic differentiation from the normal Silurian species of *Phacops.* There seems little doubt that a discriminating investigation of these Upper Silurian forms will disclose a sequence leading to blinding, very similar to that described by the Richters among the Upper Devonian *Phacopinae.*

It is singular that no blind species have been found in either the Silurian oro Devonian strata of North America. All the forms which show eye obsolescence are restricted to continental Europe and the British Isles.

In summary, secondary visual degeneration or complete blinding occurs in several branches of the European *Phacopinae* (Silurian and Devonian), and in the *Phacopidellinae.* It also appears in the genus *Ormathops (Acastinae)* which is found in much older strata (Lowest Ordovician).

Obsolescence of the eyes follows the same sequence in each case. First there is a reduction in the size and elevation of the eyes; second, the assumption of a flattened, kidney-shaped visual area; third, (except in *Nephranops*) the adoption of an elliptical visual area with a few very large facets; fourth, disappearance of the eye.

In each case, the reduction of the eyes is accompanied by a forward migration, which ends with disappearance of the eyes on the forward slope of the cheek area. In some stocks, the facial sutures continue to migrate forward after the eyes have disappeared *(Dianops, Ductina),* and in one species, *D. ductifrons* from the Upper Devonian, attain a secondarily hypoparian position.

II.—Suggested Causes of Eye Degeneration

There is no clear explanation for this extraordinary degeneration and migration of the eyes in the *Phacopidae.* If one follows the reasoning of Dollo (1910) and Perna (1915) to its logical conclusion, environment must be the deciding factor. There are distinct objections to this theory, the first being that the results obtained from examination of only a few extreme forms

(as in Dollo's studies) cannot be applied literally to the majority. Second, there is no hard and fast morphological pattern which may be invoked to suit the various physical environments in which different animals may live. One cannot say, for example, that all trilobites with large eyes lived in the dysphotic region, or that all blind trilobites were confined to the aphotic zone. The modern decapods and isopods present evidence which may bear upon this point, for they range from the pelagic zone to depths of several hundred fathoms without noticeable change in the nature of the eyes.

It is true, however, that with increase in depth, there is a distinct change in the eyes of animals without phosporescent organs. As a rule, forms which live habitually in shallow water have smaller eyes than those which live above the abyssal zone, yet in deep water (less than 1000 fathoms). But it must be emphasized that this difference in the size of the eyes seems to be the result of environment and is accompanied by no changes which suggest a phylogenetic reversion.

The comparatively stable nature and location of the eyes in the *Dalmanitidae* cannot be explained by appeal to a static environment. Although found largely in limestones and shales, these creatures also lived on sandy bottoms, indicating that they occupied various environments, although probably always confined to water of moderate depth. Had their racial stock possessed potentialities necessitating regressive migration and degeneration of the eyes, the differing environments plus racial senility would doubtless have caused it to occur. Instead, senility in this group was expressed by the production of a variety of cuticularr ornamentation. These are expressed best in such genera as *Corycephalus* and *Coronura* from the Devonian of North America.

In the stock culminating in *Phacops* and its allies, an entirely different situation prevailed. The group gave rise rather suddenly to species in which the eyes were reduced or absent. This occurred not only in the group of *Phacops* s.s. but also in several related branches of the *Phacopidae*. In every case, secondary blinding was accompanied by a migration of the eyes and facial sutures toward the antero-lateral cephalic margin. Secondary blinding was a tendency of the entire group, appearing as a phylogerontic characteristic in its various branches.

If this secondary blinding were due solely to the influence of particular environments, one would expect the blind trilobites to appear uniformly in sediments of a definite type, isolated from their congeners. This is by no means the case, as normal individuals are commonly found to occur abundantly in the strata yielding those illustrating eye degeneration. Thus there is no clear evidence that the blind trilobites or those with degenerate eyes, were affected by their environment. It is noteworthy that in every case of secondary blinding observed in the *Phacopidae*, the eyes retraced their ontogenetic path toward the cephalic margin, the acme of this tendency being reached in the completely blind *Ductina* and *Dianops*, in which the facial sutures lie along the cephalic margin. The blind species occur in the same strata with species possessing normal eyes, and to which they are rather closely related. Thus one finds the specialized and unspecialized species appearing together, a circumstance duplicated many times throughout geologic time.

If the eyes were lost because of disuse, why should they repeat the ontogeny in retrogressive fashion? It appears more reasonable to expect degeneration caused by disuse to occur without regressive migration, as in some modern Crustacea.

Raymond (oral communication) has suggested that the increase in the size of the stomach might have had the effect of crowding and inhibiting the other organs in the cephalic region. He suggests this as a possible explanation for the obsolescence and migration of the eyes in the *Phacopidae*. If this were true, one might expect all phacopids with inflated glabellae to show this tendency, but this is not the case. If the increase in the size of the stomach inhibited the development of the eyes, why should the facial sutures continue to migrate toward the cephalic margin after the eyes disappeared? In *Ductina* and *Dianops* (Upper Devonian) as figured by the Richters, the sutures do not touch the cheeks, being confined entirely to the cephalic border. In *Trimerocephalus* (Upper Devonian) the sutures traverse the anterior corners of the cheeks.

It may be, however, that Raymond's explanation is correct in part. The tendencies set in motion by the increase in size of the stomach may have continued after the eyes had disappeared, resulting in the further migration of the facial sutures. If this were the sole explanation, one would not expect eye obsolescence to appear in the Lower Ordovician *Ormathops* of the

EXPLANATION OF PLATE

FIGURES

1a-e. Variation in size and position of eyes in *Ormathops*. 1a. *O. atavus* var. *macrophthalmus;* 1b, var. *transiens;* 1c, var. *intermedius;* 1d, var. *microphthalmus;* 1e, var. *barroisi*. From R. and E. Richter (1926, p. 129, text-fig. 16).

2. Lateral view of typical species of Phacops. From Barrande.

3. *Cryphops cryptophthalmus* (Emmrich), showing the marginal position of the eyes. From R. and E. Richter, (1926, pl. 9, fig. 56a.)

4. *Cryphops cryptophthalmus* (Emmrich), enlarged view of right eye and portion of cephalon showing the position of the eye and the "*cryptophthalmus pattern*" of the visual area. From R. and E. Richter, (1926, pl. 9, fig. 56f.)

5. *Eocryphops kayseri* (Herrmann), enlarged view of the left eye showing the "cryptophthalmus pattern." From R. and E. Richter (1931, p. 145, text-fig. 4).

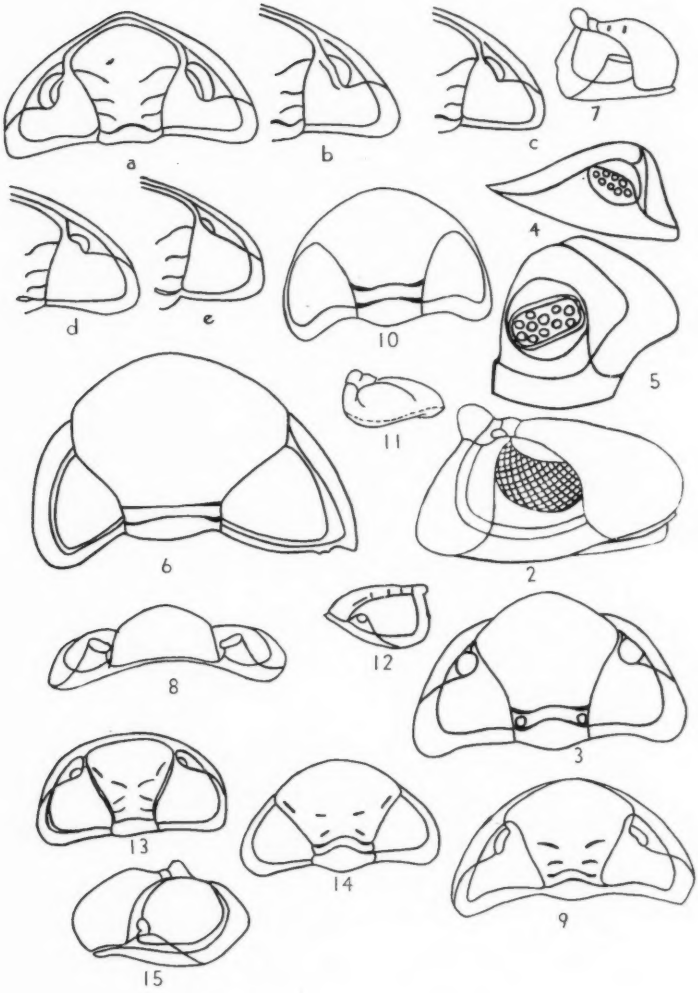
6. *Dianops limbatus* (Reinh. Richter), dorsal view showing absence of eyes and palpebral swellings. From R. and E. Richter, (1926, pl. 10, fig. 87).

7–9. *Nephranops incisus incisus* (A. Roemer). 7, lateral view; 8, anterior view; 9, dorsal view. From R. and E. Richter (1926, pl. 8, figs. 48c, 48b, 48a).

10–11. *Ductina ductifrons* Rud. and E. Richter. 10, dorsal view showing absence of eyes and palpebral swellings (1926, pl. 11, fig. 17a); 11, lateral view showing marginal position of the facial suture (1923, p. 141, fig. 1b).

12–13. *Denckmannites volborthi* (Barrande). 12, lateral view; 13, dorsal view, eyes with "cryptophthalmus pattern." From Barrande (1852, pl. 23, figs. 11, 12).

14–15. *Trimerocephalus mastophthalmus* (Reinh. Richter). 14, holotype originally figured by Munster as *Trinucleus? laevis* (1842, pl. 10, fig. 6), from R. and E. Richter (1926, pl. 9, fig. 68a; 15, a cephalic cast showing the palpebral swelling which is usually not developed. From R. and E. Richter (1926, pl. 10, fig. 75).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Bohemian Basin, which did not possess an inflated glabella, yet showed both reduction in size and migration of the eye. On the other hand, those *Phacopidae* which show the highest glabellar inflation yet observed, *Bouleia* and *Dereimsia* (Lower Devonian of Bolivia), show no apparent eye degeneration. Hence other causes for secondary blinding must be sought.

The recent work of Lalicker (1935) on larval forms of trilobites from the Middle Cambrian of Alabama casts some interesting light on the circumstances detailed above. As summarized by both Lalicker and Raymond (1935), the results of the investigation suggest that the eyes of trilobites may have first appeared on the dorsal surface. The appearance was spontaneous, apparently occurring at some not yet determined critical moult. This observation, if substantiated by further findings, will tend to disprove the current concept that the eyes developed on the ventral surface and subsequently migrated to a dorsal position.

The blind Devonian species suggest a reversal of the developmental pattern outlined by Lalicker. It may be likened, in a general way, to the gerontic uncoiling of the ammonite cephalopods during Cretaceous time. It is not clear, however, what circumstance or combination of events furnished the plasmic impact necessary to begin the sequence of regressive stages which culminated in such blind forms as *Ductina* and *Dianops*. The motivation may have been supplied by changing physical environment, or by modification of eating habits and hence of cephalic structure. In any event, once under way, the regressive development proceeded to its natural conclusion, with the approaching end of phacopid existence doubtless assisting in the completion of the process.

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Book Reviews

DIE STAMMESGESCHICHTLICHEN GRUNDLAGEN DER ABSTAMMUNGSLEHRE. Von K. Beurlen. Jena, Gustav Fischer, 1937. viii + 264 pp. RM 10,50.*

Originally the theory of descent was deductively formulated as a mental construction out of findings obtained from living organisms. The fossil record which should really have furnished the natural basis for the purely historically constructed theory of descent, instead of the picture derived from present conditions, was neglected to a considerable degree both by its originators (Lamarck and Darwin) and by its later exponents right up to the present time. But meanwhile paleontology has come of age sufficiently to provide decisive contributions to the criticism and the further elaboration of the theory of descent. In the present work K. Beurlen endeavors on a grand scale to present by means of numerous examples the actual course of the phylogenetic process and to place it into the center of a true theory of descent historically conceived. In doing this, his wide purview ranges back even to ideas of antiquity and he begins by outlining "the ideological history of the theory of descent."

Next, he clearly states the law peculiar to the phylogenetic process which expresses itself above all in the fact of irreversibility and in the different regularities in the course of the process, i.e. the phylogenetic increase in size, orthogenesis, over-specialization, the iterative structures etc. This regular course of phylogeny following its own laws indicates that phylogeny is not dominated by accidental features hence is not subject to a mechanistic interpretation. Irreversibility is not as heretofore considered a "phylogenetic law" but as the logico-categorical and fundamental form of the historic.

Wholeness represents another category of organic matter. Not only does the individual organism represent a holistic Gestalt but the higher phyletic units of which it is a member are also holistically constructed. The phenomena of parallel evolution, of over-specialization etc. become comprehensible only by the fact that the "phyletic Gestalten," i.e. the units superior to the individual are real, holistic realities. Consequently a hierarchy of holistic levels of varying degrees is to be accepted. The individual developmental stages: youth, maturity, age and death, are correspondingly expressed in the phyletic units. The extinction at the end of a phyletic cycle, for instance, is as a phyletic death essentially the same as the death of the individual.

The evolution of phyletic forms is analogous to that of the individual forms in constant combat with environment. This calls for a detailed analysis of the concept of adaptation. Since it implies a pronouncedly subjective interpretation of facts it is to be entirely excluded, according to the author, from the concepts of phylogenetic and biological research in general. The organism does not adapt itself mechanically to its environment but it constructs its milieu fitted to its organization so that it then obviously fits into it. If changes of the environment occur the organism does not adopt the line of least resistance but undertakes counter measures by which it offsets the influence of the environment on the milieu constructed by itself (an idea which has in similar form been maintained already by H. Quiring). These counter measures are designated following Böker as "active reorganizations" (Umkonstruktionen). The author considers them equivalent to the modifications of genetics and supposes that they become hereditary and change the genotype provided the conditions persist over a long period of time.

The direction along which these reorganizations, and consequently the differentiations, take place is not a predetermined one but caused by the particular environmental conditions. The development of structure is therefore not preformed but purely epigenetic. "The impression of an orthogenetic evolution arises but for the reasons that

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each new reorganization must take place within the limits of its predecessors and that it further reduces the number of the possible diverging directions."

The capacity for reorganization is however type-linked; it never leads beyond the limits of the given type. Another process is responsible for the origin of new type organizations, i.e. that of neomorphosis. While one deals with an ontogenetic prolongation in the case of orthogenetic evolution within the limits of the types, i.e. a prolongation of the individual cycle from generation to generation by the individual steps of reconstructions, neomorphosis consists in an abbreviation of the individual cycle, i.e. in a new formation proceeding from the juvenile stages onward. The mere fact emphasized by the author that the new type begins with relatively small forms in contrast to the preceding one is supposed to show "that the change to a new type always takes place by way of a rejuvenation, i.e. an abbreviation of the individual cycles." As an explanation of this phenomenon it is suggested that inhibitive external influences have led to neoteny and that the latter has finally become hereditary.

Viewed as a whole phylogeny is described "as a progressive conquest of the environment for the immediate milieu dominated by the organism. The most primitive organisms had still a restricted and poorly differentiated milieu anad were therefore structurally dependent upon the particular environment whereas in the more differentiated organisms the milieu was extraordinarily enlarged and the dependence upon the environment largely overcome. Orthogenesis and neomorphosis—the collecting of experience in the environment by specializations and incorporation of these experiences into the organization—are the external modes in which and by which this conquest took place. As means which organic nature had produced for this purpose we recognized inheritance, the capacity for reorganization, sexuality, and the somatic individualization as a consequence of the separation of soma and germ track."

Behind the organic fundamental properties of the capacity of inheritance and reorganization is supposed to exist as the ultimate and actual reality of life an active force which is designated as the will to self-structure=will to exist=will to power. The final chapters lead then more and more over into purely logical or transcendental realms, respectively, and treat among other things the problems of "causality and freedom in the organic," the "antithesis organic-inorganic," "objective and essential mode of thought," "race, world view and mode of thought."

These are roughly speaking the leading principles of the book which is not written in an easily readable style, but is extremely stimulating. The multitude of original ideas deserves mention as well as the precise formulations and the perspicuous examples frequently presented in a new light. A short review can by no means do justice to the wealth of thought; therefore a detailed study of the work itself is highly recommended as indispensable for everyone who intends to devote himself to problems of organic evolution.

In such an inclusive work which embraces within its scope the most divergent fields of biology and philosophy it is but natural that some objections are possible and that some details are well capable of different interpretation. We choose as examples but the following: the geneticists will hardly subscribe to the author's statement "that the concepts of genetics have failed with regard to the real problem of inheritance," and furthermore that the dichotomy of a genotype existing as a pure abstraction only and a phenotype, is but the outgrowth of a dilemma. Likewise objections will be raised from this quarter to the acceptance of a heritable fixation of modifications. The interpretation of the author leads thus again, in spite of his assertions to the contrary, to a sort of Lamarckism.

Students of the Foraminifera will flatly contradict the statement made in accordance with Harms that there exists no constancy of species among unicellular organisms, no inheritance and consequently no real phylogeny. Contrary statements of most recent date are available, e.g. by Glaessner, Tan Sin Hok and Thalmann. Likewise will it be impossible to approve entirely the discussions in the form presented regarding the different concepts of species and genera in the various groups of organisms.—We leave aside whether or not the "will to exist" or the "will to power" is a really explanatory and revealing principle. It is hardly of a different nature from Bergson's élan vital or other similar expressions. Whether or not moreover the notion of objective and

essential mode of thought is very fortunately formulated the philosophers may decide. Likewise a verdict with regard to the general discussions on freedom and causality, accident, the concept of time etc. may be left to them. It seems to the reviewer that here too some objections and deviating views are possible.

The great merit of the present work is however not lessened by such individual objections. We welcome it as a courageous and timely attempt to interpret paleontological facts in a new siprit and to weave them harmoniously into a complete biological picture conceived on a grand scale.—O. H. SCHINDEWOLF.

GENETICS AND THE ORIGIN OF SPECIES. By Theodosius Dobzhansky. Columbia Biological Series No. XI, edited by L. C. Dunn. New York, Columbia University Press, 1937. xvi+364 pp., 22 figs. $3.60.

Modern experimental biology is constantly accumulating information towards our understanding of the forces behind the "origin of species." Moreover Prof. L. C. Dunn tells us in the "Editor's Preface" to the present volume that "there was need for such a summary and synthesis of the new experimental evidence, and for reassessment of the older theories." Every reader seriously interested in both the progress of genetics and the present status of evolutionism will gladly subscribe to this statement for the book does represent the most thorough-going and actually up-to-date summary of genetical knowledge and its bearing on evolution published so far. In fact if the book is used in conjunction with certain recent paleontological, or more specifically, phylogenetic treatises it should be possible to draw a rather complete picture of current biological thought regarding evolution.

The book itself is "devoted to a discussion of the mechanisms of species formation in terms of the known facts and theories of genetics." In doing so the author assures us that "the treatment had to be made assertive rather than polemic, dogmatic rather than apologetic." Such an attitude is not only justifiable but highly commendable for the general consensus of today is to consider evolution as a process postulated by reason and not affected by the validity or disproof of certain theories advanced to explain it. Thus little space is given to Lamarckism and detailed discussions of certain objections to evolutionism, especially the frequently made assertion that genetics deals only with "micro-evolutionary phenomena" not touching the crux of the process, i.e. macro-evolution. This the author solves by instructing us that "a geneticist has no choice but to confine himself to the micro-evolutionary phenomena that lie within reach of his method, and to see how much of evolution in general can be adequately understood on this basis."

The book opens with a chapter on "Organic Diversity" an obvious expression of the multitude of living beings and variation among individuals with due recognition of its discontinuity. In the analysis of organic diversity and its theoretical interpretation by evolution two distinct phases may be recognized: a) evolutionary statics (Chapters II-IV) and b) evolutionary dynamics (Chapters V-X). The former concerns itself with the forces that may bring about changes "in the genetic composition of populations" whereas the latter deals with "the interactions of these forces in race and species formation and disintegration."

Chapters II-X are devoted to the various "mechanisms of evolution" as the geneticist sees them. They may be enumerated as follows: gene changes or mutations s.str., chromosomal changes (e.g. position effects etc.), and polyploidy. In order to become effective changes must pass through three levels of the evolutionary process, viz., 1) the origin of mutations and chromosomal changes, "governed entirely by the laws of the physiology of individuals"; 2) the injection of mutations s. lat. "in the genetic composition of the population, where their further fate is determined by the dynamic regularities of the physiology of populations"; or the level "on which the impact of the environment produces historical changes in the living population"; 3) the "realm of fixation of the diversity already attained on the preceding two levels"; active agents in the prevention of interbreeding of "races and species as discrete arrays of individuals" are "ecological isolation, sexual isolation, hybrid sterility and others." The

analysis of the latter is "one of the most important problems of the genetics of populations."

The introduction of such factors as criteria into the treatment of the species problem (Chapter X) led the author to propose the following definition of a species as being "that stage of evolutionary process, 'at which the once actually or potentially interbreeding array of forms becomes segregated in two or more separate arrays which are physiologically incapable of interbreeding'." Thus the species is here considered "a stage in a process, not a static unit." The systematist is assured that his species coincides largely with the above given definition.

Appended are 28 pages of literature giving evidence of the sources from which material was drawn. Thus much information of otherwise somewhat inaccessible character (e.g. Russian work) has been made available. The recent dates of publication are certainly numerous and add much to the timely nature of the book. An index concludes the volume.

While some quarters and individuals may single out certain statements as open to discussion biologists should indeed be grateful for this scholarly exposition of the results of modern genetics and appreciate the critical evaluation of this material in the light of evolutionary concepts.—TH. JUST.

NEUE UNTERSUCHUNGEN über die fossilen Insekten, mit Ergänzungen und Nachträgen sowie Ausblicken auf phylogenetische, palaeogeographische und allgemein biologische Probleme. Von A. Handlirsch. Ann. naturh. Mus. Wien **48**: 1-140, 1937.*

The Museum of Natural History in Vienna has generously undertaken to publish the posthumous work of Handlirsch intended as a supplement to his "Die Fossilen Insekten." Special thanks are due to Dr. K. Holdhaus, director of the division of zoology, who has taken great trouble to prepare the ms. for print. The first part now available in printed form treats of general problems as well as of the insects of the Paleozoic. Unfortunately the ms. of Handlirsch does not cover the years after 1930 hence his contribution is in some ways already out of date again; yet it is valuable as the legacy of the best known and probably best informed of all paleo-entomologists.

The general section of the work deals with the relative completeness and lacunae of the paleontological record, with the problem of the derivation of all arthropods from the trilobites, with the origin of the insects in particular, with wings, segments, extremities of insects, their tracheal system, and with the segmental organs.

The author emphasizes the fact that paleo-entomology has progressed far enough to serve as a valuable aid not only to the student of phylogeny but also to the animal and paleo-geographer, and that there exists even for the zoologist studying recent animals the obligation to use in his researches the material provided by the paleontologist.

The position of the trilobites among the arthropods. The author is unable to change his previous view regarding the central position of the trilobites in the phylogenetic tree of the arthropods. He considers as the most primitive trilobites the homonomous polymerous types, i.e. *Triarthrus*, in which the number of segments is not as yet definitely delimited. He is however aware of the fact that the evolution of the trilobites from chaetopods has taken place long before the beginning of the Cambrian, and that the great majority of the trilobites known to us can not be considered as the ancestors of the other groups of arthropods but are rather more or less closely related.

The trilobites are according to the author the ancestors of all higher arthropods. The series leading from the trilobites to the Arachnida is according to him most easily traceable. *Olenellus* is considered as an important principal type in this connection as well as elsewhere in the work. Intermediate forms are *Strabops*, *Aglaspis*, *Molaria*, *Habelia*, *Emeraldella* and *Leanchoilia* from the Cambrian. "With these can

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be without trouble connected the group of the Gigantostraca. . . and in addition the group of the Xiphosura. . ., which can not be derived from each other but only from ancestral types which were probably still on the level of the Aglaspinae. . ." The terrestrial scorpions have evolved from primitive Gigantostraca (probably *Eusarcus scorpionis*).

Less clear is the connection between the trilobites and the Crustacea. *Marella splendens* Walc. from the Cambrian "in which all segments bear still trilobite-like bi-ramous legs while the pleura of the segments have vanished almost completely" is considered as an almost intermediate form. The author derives tentatively the Arthropleura from the Isopoda.

Likewise the author derives the Myriapoda from the trilobites by using certain Carboniferous and Devonian forms described by Fritsch, Scudder and Peach (i.e. *Archidesmus loganensis* Peach and *Kampecaris forfarensis* Page from the Scottish Devonian with compound eyes reminiscent of *Phacops* and broadened legs.)

The phylogeny of the insects is treated by the author in a separate chapter. He finds that much material supporting his trilobite-theory has been revealed in the 20 years which have lapsed since the publication of his handbook of fossil insects (at the time of completion of the ms., 1931). The Collembola-theory of Tillyard is rejected in a high-spirited fashion. At best only the Thysanura can be considered among the Apterygota as "Ur-Insekten" (primitive insects). Only in this group are normally retained both compound eyes as well as ocelli, the segments in the number typical and normal for the Pterygota (20 + telson), antennae and cerci correspond to those of other primitive insects, the mouth parts are similar to those of primitive Pterygota, the thoracic legs still possess styli indicative of an origin from biramous extremities, and on the lower side of the abdominal segments rudimentary legs have been retained.

The Myriapoda can not be considered however as the ancestors of such wingless primitive insects, in fact none of their groups. No more can higher Crustacea be considered (this view was recently refuted by Calman as well), a derivation from the Chelicerata is wholly absurd and the Onychophora can not be used either. Thus the author arrives, per exclusionem, at the end of this chapter again at the trilobites as ancestors of the insects as well. "The gap is considerable to be sure, but no longer unsurmountable." The author attempts to elaborate this in the subsequent chapters.

The wings of the insects. Of the different theories proposed regarding the origin of the insect wings only one is tenable. Morphologically speaking the wings are conduplications of the body wall (tergites) of the second and third thoracic segment. Paranotal lobes which are homologous to the wings as far as found on the second and third thoracic segment can be observed on the larvae of *Silpha* and other beetles as well as adult Blattariae. In such forms it can be noticed that the young larvae possess pleura which have the same appearance on all segments. Only in the older larvae does there appear a differentiation of the pleura of the second and third thoracic segment in order to produce the wings after the last ecdysis. One can only agree with the author if he considers this process a repetition of the phylogenetic course of development. Such pleura are on the other hand a group character of the trilobites and in the juvenile stages of *Olenellus* the pleura of some segments are even larger than those on others.

The author then treats some of the theories of venation advanced of late by describing briefly Adolph's fan theory with its regular sequence of convex and concave veins and by relating how Redtenbacher who accepted this theory at first departed from it later on. Comstock and Needham based their work on Redtenbacher's researches and developed a general terminology of the main veins of the wings on an ontological basis. A prototype of venation of the insect wings could thus be determined which conforms to a far-reaching extent with the venation of the oldest known flying insects, the Palaeodictyoptera. However the author is of the opinion, no doubt correctly so, that the determination of homologies of the branches and branchlets of the main veins practiced in many instances leads too far since the evolution of the branches takes place in many directions. This is certainly the case though it was found occasionally by special study that even the secondary and tertiary branches of the veins remain remarkably constant and are retained for a long time in the course of phylogeny. In

such cases the determination of homology of the branches of veins is possible even in but remotely related groups, and the author certainly goes too far in the refutation of this method.

The author deplores correctly that Adolph's theory has recently been "warmed up" again by Lameere whose study on wing venation he considers actually as a regression. Lameere is of the opinion that all main veins were originally divided dichotomously with the anterior branch convex and the posterior one concave. But it can be shown that in the course of phylogeny convex veins have become concave on several occasions and v.v., and that even one and the same vein can assume at times a convex course for part of the way and then revert to a concave one. Lameere's theory can hardly be maintained for these and many other reasons listed by the author.

The author adopts a reserved attitude towards the contribution on the morphology of the wings published in 1929 by Vignon. Martynov's Palaeala-Neala-theory which has been unanimously refuted outside of Russia is refuted also by the author by claiming the fact that the anterior part of the wing both in the front and hind wings designated as Neala is very differently constructed in the different groups thus making a monophyletic origin inconceivable.

Likewise the segmentation of the wing proposed by Berlese into four subsequent segments, Anteala, Praeala, Interala, and Postala, which is based on the supposed quadri-segmentation of each thoracic segment finds no basis of verification in paleontology. Consequently one may say that all recent theories have been found untenable and thus prove directly or indirectly the views held in part by Comstock and in part by the author as far back as thirty years.

The segments and their extremities. The author considers it a proven fact that the head of the insects consists of the pre-oral region or acron and six metameres namely the ocular, antennal, intercalary, mandibular, 1. maxillary and 2. maxillary segments. He maintains the viewpoint moreover that originally fourteen postcephalic segments are or were present, respectively. Three of these belong to the thorax and eleven to the abdomen. To these must be added the telson which may be designated if so desired as the 12th abdominal segment. The existence of the disputed 11. segment (between the 10th and the telson) is proven on recent as well as fossil forms according to the author although it is often entirely reduced. This eleventh segment bears the cerci what is especially easily recognized on *Lycocercus golldenbergi* Br.

Although the extremities of the insects appear today uniramous many traces of an original biramous nature may be shown what proves once more according to the author the derivation from the trilobites. Only the antennae and the cerci have always been uniramous. In the following the author speaks of indications of original abdominal extremities as well as indications of the original biramous nature of the extremities.

Tracheal system and segmental organs. The author agrees with the school of Arn. Lange in Zürich which tries to derive the tracheae from segmental organs, i.e. nephridia, for this segmental theory explains some phenomena formerly overlooked and since it facilitates moreover the supposition of an independent origin of tracheae in insects, Myriapoda, and spiders.

Insects of the Carboniferous. It is impossible to review here in detail this chapter. The forms described anew since the publication of the handbook and prior to 1930 are discussed therein on 40 pp. with the addition of many annotations regarding the phylogeny of the groups. Only a few matters may be mentioned here. The finds of Apterygota described by Hirst and Maulik (not Manlik) from the Middle Devonian of Rhynie (Aberdeenshire) are considered by the author as most dubious. Meanwhile new finds have been made as Calman reported recently which are to be described by Scourfield and which reveal unmistakably that there can be no longer any doubt regarding the insect nature of these "Collembola." Consequently specialized Apterygota existed as early as the Middle Devonion. Since the phylogenetic line of the Pterygota has certainly not passed through these Apterygota the hostile attitude of the author is to be explained primarily on a psychological basis. His heories are not touched by these findings on any essential point.

The author turns with great detail against the classification of insects by Lameere

in which he tries to divide the Palaeodictyoptera into "Subulicornia" (Ephemeroptera and Odonatoptera) and Hemiptera.

The author follows justly the terminology of the veins in the wing of the Odonata by Comstock who was able to show unmistakably by the use of photographs how Rs becomes superimposed over the two first branches of M in the wing of the nymph and thus produces the crossing-over. Tillyard and Lameere have incorrectly given up Comstock's interpretation.

In place of the attempts to subdivide the Protorthoptera as done by Lameere and Martynov the author proposes a preliminary division into the suborders Geraroidea, Cacurgoidea, Caloneuroidea and Oedischioidea by the exclusion of forms related to *Cnemidolestes* as a separate order Cnemidolestoidea. This division seems to me to go too far. The groups deserve at best family rank; hence it is more advisable to retain the author's old classification.

The Blattariae are treated very extensively by enumeration and discussion of the individual species.

Tillyard's Protohymenoptera are considered by the author too as highly specialized Megasecoptera.

The Insect Fauna of the Permian. This chapter is already out of date again for many hundred new forms have been described since 1931. It is therefore unnecessary to enter here into a discussion of details although many valuable remarks are found therein regarding the interpretation of phylogenetically interesting finds.

Tillyard's *Protocoleus mitchelli* fits according to the author very well into the hypothesis that the Coleoptera are derived from Protoblattoidea. The Protoperlaria and the Panorpoid-complex are treated very extensively. This is followed by an index of all known Permian insects (up to 1930).

In general the author has deviated but little from his previous views and one gains the impression that in many instances he has done the right thing. Even today Handlirsch's classification of insects is still the best founded.—F. ZEUNER.

AN OUTLINE OF GENERAL PHYSIOLOGY. By L. V. Heilbrunn. Philadelphia, W. B. Saunders Co., 1937. 603 pp., 112 figs. $5.00.

General physiology may be variously delimited. Hence available treatises will differ correspondingly. The author of the present volume wrote it largely because he considered the field as "a science in its own right" and intended the book to present "an adequate summary of existing literature." A perusal of the product will convince the reader at once that both aims have been admirably and successfully achieved. Called modestly an "outline" the professional physiologist may well consider it such whereas the biologist primarily concerned with other phases of his science though interested in physiology will gladly reach for the book in time of need and find himself well guided and instructed by it.

General physiology is as the author understands it "the science which deals with all forms of living material," and "it attempts to answer the question, 'What is Life?'." Since modern biology considers the cell "the unit of living matter" the obvious conclusion would be that general physiology can be identified with cellular physiology. Yet it seems in no way compulsory to do so for sciences are whatever their "devotees choose to make" them.

Being of rather recent origin general physiology does not possess as yet the earmarks of careful organization so characteristic of other well-established sciences. The author has therefore adopted what seems to be a well-conceived sequence of chapters, beginning the book with a short treatment of the "statics of living systems" whereas the greater part of the volume is devoted to "kinetics." These chapters cover a wide range of properties and problems ending with a short discussion of reproduction.

The observant reader will be pleased to find a large number of references of very recent date (inclusive of 1937) and to many somewhat obscure sources. Such detailed

citation and verification of statements made is generally not a characteristic of "Outlines." The carefully prepared indices to authors and subjects unquestionably enhance the usefulness of the book. Botanists will be pleasantly surprised at the balanced content of this "General Physiology."—TH. JUST.

GESCHICHTE DER BOTANIK von den ersten Anfängen bis zur Gegenwart. Von Martin Möbius. Jena, Gustav Fischer, 1937. vi + 458 pp. RM 20,00.

It was a very happy thought indeed to bring "up to date" the classical accounts of botanical history. The author had the good fortune to begin his botanical career in the 19th century in personal contact with that grand period of expansion along all lines of scientific knowledge and to witness during a long and busy life the advent and ascent of many new fields of botanical investigation. This coincidence determines to a large degree the character of the book.

What might comprise the bulk of another history is here covered in approximately 100 pp. (to be sure this is not the only early history found in the book) whereas the remainder is reserved for the special histories of the various fields. In addition to "Scientific Botany" "Applied Botany" is also reviewed in its historical development though on much less space. A third part presents the history of "Aids in research and teaching of botany." The first two parts are each subdivided, particularly part I in which the entire early history is told and subsequently group by group, science by science, and function by function are taken up. Thus we find e.g. 8 pp. devoted to lichens (pp. 107-114) and about 7 pp. to the ascent of sap (pp. 260-266) to mention but two. Personal notes and dates etc. are given in footnotes in order to avoid encumbering the text. Much valuable information is found here, mostly on botanists of today and yesterday, though not always complete, cf. p. 354.

Such a treatment results obviously in a peculiar situation. While certain phases will stand out conspicuously others no doubt are bound to suffer. It may well be convenient to have the "subject-histories" arranged this way, yet much is probably lost as far as the description of the great movements is concerned. Also one wonders at times at the selection of material, contributions made and the evaluation given them. Perhaps we have as yet not gained that perspective required of objective historical presentation. Yet one can not be wholly without the impression that in many instances we read a review ("Sammelreferat") of a certain field and wonder at the versatility with which the author seems to suceed in covering so wide a range of fields. The peculiar apportionment occasionally betrays the author's personal preferences. However such discrepancy may be readily excusable in view of the stupendous amount of available literature and data as well as the intricate connections existing between the various fields of botanical research.

Botanists will thank the author for describing the development of their science in all its ramifications up to the present. In this the book is the first of its kind and will constitute a worthwhile addition to botanical libraries.—TH. JUST.

ANNALES BRYOLOGICI. A Year-book devoted to the study of mosses and hepatics. Edited by Fr. Verdoorn. Leiden, Chronica Botanica Co., 1937. Vol. IX (1936), 160 pp. 6 fl.

Since 1927 "Annales Bryologici" have with their supplementary volumes assumed a leading position in the field of bryology. With Vol. IX they appear in a wholly new form with many special features of international interest added, viz. "Summaries of Recent Research" (cf. Bericht über einige neuere karyologische Arbeiten an Moosen, von W. & Ae. Döpp), "Bryophyta Nova," and "Miscellaneous Notes" reserved for announcements of Societies and Commissions, death notices of famous bryologists, reviews etc. The Contents reveals articles of the same standards as in previous volumes. The increase in size coupled with the low cost will assist in their gaining a wider circulation. This would be highly desirable for Annales Bryologici have become so well established by now that their absence would leave a conspicuous gap. An index might increase the general usefulness of the volume.—TH. JUST.

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